From Science to Management and Back: A Science Forum for Southern Interior Ecosystems of British Columbia

[Title supplied by the cataloguer]

From Science to Management and Back: A Science Forum for Southern Interior Ecosystems of British Columbia

- On the brink of knowing
CHRIS HOLLSTEDT [30KB]

- The role of science in results-based planning and management
HENRY BENSKIN [52KB]

- Identifying specific indicators of sustainable forest management
R.A. LAUTENSCHLAGER [50KB]

- Forest resource research in the Cariboo Forest Region
JANE PERRY, KEN SONEFF, AND CLAIRE TRETHEWEY [52KB]

- From the individual to the organization: Our cultural roots affect our decisions
ANN SCHAUBER [39KB]

- Achieving a globally competitive industry: Using science, innovation, and best available knowledge
BILL BOURGEOIS [42KB]

- Effectiveness of repeated manual cutting of mixed-shrub vegetation in an Interior Cedar-Hemlock zone spruce plantation: Fifth-year results
PHILIP COMEAU AND BALVINDER BIRING [62KB]

- Armillaria root disease: A major impediment to sustainable management of southern Interior ecosystems
DUNCAN MORRISON [102KB]

- Riparian management and stream temperature
PATRICK TETI [43KB]

- Update on soil rehabilitation research in the southern Interior
CHARLES BULMER, SHANNON BERCH, BILL CHAPMAN, MIKE CURRAN, DEREK HODGKINS, GRAEME HOPE, MELANIE JONES, MATTHEW PLOTNIKOFF, MARGARET SCHMIDT, KIRSTY VENNER, AND GUOPING XIAO [60KB]

- Barriers to integrating science into policy and practice
CHRIS HOLLSTEDT AND KATHIE SWIFT [42KB]

103-06775/

- Timber supply and aesthetics at the landscape level: A fresh look at an old problem
STEPHEN SHEPPARD AND PAUL PICARD [167KB]

- Old-growth structural attributes in managed forests: Is there a vision?
THOMAS SULLIVAN, DRUSCILLA SULLIVAN, AND PONTUS LINDGREN [45KB]

- Refining definitions of old growth to aid in locating old-growth forest reserves
TOM BRAUMANDL AND RACHEL HOLT [59KB]

- EcoGen: A model for predictive ecosystem mapping
DEL MEIDINGER, BRUCE ENNS, ALLEN BANNER, AND COLLEEN JONES [146KB]

- We're harvesting timber and maintaining caribou habitat: What about silviculture and other concerns?
TERESA NEWSOME, MICHAELA WATERHOUSE, HAROLD ARMLEDER, AND ORDELL STEEN [71KB]

- From here to eternity: The perils of policy analysis
MARVIN ENG AND EVELYN HAMILTON [136KB]

- Designing an adaptive management field project: A case study
VERA SIT AND BRIAN NYBERG [57KB]

- GIS and the visualization of First Nations resource management
JOHN LEWIS [40KB]

- An innovative approach to extending knowledge
TRINA INNES [54KB]

- First-season growth of lodgepole pine seedlings grown in three different container types and planted on landings, or on burned or unburned sites
MELANIE JONES, ANNE JOHNSON-FLANAGAN, STEVEN KIISKILA, AND CHARLES BULMER [83KB]

- Brushing for future forests or free-growing requirements?: One to five year PROBE results
SUZANNE SIMARD, JEAN HEINEMAN, AND JEAN MATHER [49KB]

- Native grass seed development
MANIVALDE VAARTNOU [49KB]

- Tree encroachment in the south Okanagan and lower Similkameen valleys of British Columbia
JENNIFER TURNER AND PAMELA KRANNITZ [49KB]

- Range Reference Areas: Determining seral stages and vegetation change on permanent range in British Columbia
WAYNE ERICKSON [48KB]

- Effects of grazing on soil compaction and water infiltration in forest plantations in the Interior of British Columbia
KLAAS BROERSMA, MAJA KRZIC, REG NEWMAN, AND ARTHUR BOMKE [127KB]

- Cut-to-length partial-cutting trial in the Okanagan
ERIC PHILLIPS [50KB]

- Alternative silvicultural systems: Harvesting logistics and costs
JANET MITCHELL [54KB]

- Testing forest vegetation management options in British Columbia
BALVINDER BIRING AND PHILIP COMEAU [61KB]

- Partial cutting in root disease infected stands in the Interior Cedar-Hemlock biogeoclimatic zone
DEB DELONG, PHILIP COMEAU, AND CINDY PRESCOTT [172KB]

- Retrospective studies of soil conditions and forest productivity on rehabilitated landings: Interior of British Columbia
MATTHEW PLOTNIKOFF, MARGARET SCHMIDT, AND CHARLES BULMER [138KB]

- Litter decomposition in British Columbia forests: Influences of forestry activities
CINDY PRESCOTT AND LEANDRA BLEVINS [48KB]

- Effects of opening size on soil ecology and nutrient cycling in a high-elevation, southern Interior forest
GRAEME HOPE, RALPH ADAMS, DANIEL DURALL, SHANNON HAGERMAN, GARY HUNT, KATHLEEN JOHNSON, MELANIE JONES, HANNAH NADEL, CINDY PRESCOTT, DONALD SACHS, SYLVIA WELKE, AND MICHAEL FELLER [58KB]

- Volume loss of Douglas-fir infected with Armillaria ostoyae
MIKE CRUICKSHANK [55KB]

- Potential of woody understorey plants to provide refuge for ectomycorrhizal inoculum at an Interior Douglas-fir forest after clearcut logging
SHANNON HAGERMAN, STACEY SAKAKIBARA, AND DANIEL DURALL [115KB]

- Effects of riparian buffer width on high-elevation songbird communities
DEVON HAAG AND THOMAS DICKINSON [59KB]

- A systematic method for identifying priority conservation areas using wildlife habitat relationships and observed locations of rare species
LEANNA WARMAN AND ANTHONY SINCLAIR [75KB]

- Small mammals and stand structure in young pine, seed tree, and old-growth forests in southern British Columbia
THOMAS SULLIVAN, DRUSCILLA SULLIVAN, AND PONTUS LINDGREN [44KB]

- Indigenous knowledge and occidental science: How both forms of knowledge can contribute to an understanding of sustainability.
CHARLENE HIGGINS [87KB]

Note: All papers optimized for Adobe Acrobat Reader 4.

On the brink of knowing

CHRIS HOLLSTEDT

"If resource management is inherently uncertain, then surprises become opportunities to learn rather than failures to predict" — Kai Lee, 1993

I read this quote several years ago and wrote it down to remind me how humbling it is to be a professional forester. I was reading up on sustainable forest management. For some reason this quote captured the essence of my quandary. If resource management is risky business, what is my role in limiting the risk?

Well, the fact is that resource management is risky, but it is managed risk. The province of British Columbia has invested in research and technology development for over 50 years. Much of this information is reflected in the practices of today. But the new challenges of ecosystem-based management and the creation of policies and practices that can withstand the scrutiny of the global community put new pressures on us to know more. We must be able to demonstrate that we are managing sustainably. We must admit when we're not sure and make a concerted effort to study our effects on society and the land.

Resource management in British Columbia is moving from timber-based management to ecosystem-based management. The new-age natural resource professionals (and organizations) must manage for a balance of social, economic, and environmental needs while ensuring future generations have the same opportunities. They must be students of the sciences, of risk, ecosystem, and adaptive management, as well as sustainability, social forestry, indigenous knowledge, global economics, forest certification, and information technology. And last—but not least—forest policy. This is not an exhaustive list, but it does demonstrate the need to integrate across disciplines and organizations to achieve the balancing act.

Now, more than ever, we must plan for future conditions and be prepared for the inevitable surprises so that we can continue to learn and be ready for the next era in natural resource management. We are on the brink of knowing what we don't know and leaning over the edge to an era of community-based learning.

This gathering is about being prepared for that future, while managing for today. I was tempted to call this the "no surprises forum," but in reality there will always be surprises. We should look to them as opportunities to learn, rather than failures to hide. This forum is called "From Science to Management and Back." I encourage you to share your ideas on the information presented, to discuss how this information might be used in your management now, and to identify opportunities to work together to find solutions for future management. When you come across a "surprise" you will be able to share your story at the next forum.

On behalf of the Partnership, welcome.

Citation —

Hollstedt, C. 2000. On the brink of knowing. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 1.

The role of science in results-based planning and management

HENRY BENSKIN*

I would like to compliment the Southern Interior Forest Extension and Research Partnership for taking the initiative to put on a forum with a "science to management and back" theme. To the best of my knowledge, this is a first in British Columbia. And, it is a very timely initiative considering the ever-increasing interest in a scientifically credible foundation for sustainable forestry from a wide variety of client groups, including:

- policy developers;
- statutory decision makers;
- certification proponents and adjudicators;
- innovators across the forest sector;
- educators and trainers;
- professionals and skilled workforces; and
- First Nations, communities, interest groups, and the general public.

Results-based planning and management, as a strategy, will attract the interest of all of these client groups. Each will have views and expectations about the role of science, what science is needed, how it is best communicated, by whom and in what form.

So, I'm pleased to see some members of these client groups have made the effort to attend and contribute to this forum. Together, the providers and users of information have an opportunity to develop insights and a common perspective to move the "science to management" agenda forward.

Before getting into a discussion of my topic, I would like to take a moment to define what I mean by "results-based." This term has become a buzzword which is used in various contexts, and probably with many different meanings. The forest industry has recommended revisions to the Forest Practices Code to make it more "results-based"; and public submissions to the Forest Policy Review seek empowerment of local communities to undertake "results-based" management. At one end of the spectrum, are individuals who are simply saying "just get out of my way and let me get on with doing what I think is best." However, to me a results-based approach to forestry is a lot more rigorous than that.

Our management concepts can be categorized in numerous ways. I've divided them into three broad groups: administrative, results-based, and a range of hybrids between the two. Although I have heard arguments to the contrary, I continue to think that today we operate primarily under an administrative model.

The key feature of this model is that the measure of success is full compliance with the rules or a set procedure. The rules or procedures themselves may be based on an anticipated result, but once they are developed, it is the detailed rules and procedures that become the focus of implementation and

Citation —

Benskin, H.J. 2000. The role of science in results-based planning and management [Keynote address]. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 3–6.

monitoring. I am sure that we all have our own views on what is the appropriate level at which to define the rules, whether it be at:

- the level of specific actions (e.g., stream crossing);
- the activity level (e.g., prescribed burning);
- the block level (e.g., free-growing specifications);
- the landscape unit level (e.g., percent old seral targets); or
- the management unit level (e.g., cut control).

The point I want to make is that although we have streamlined some aspects of operational planning, current processes still have a strong administrative orientation, where statutory decision makers must approve block-specific plans containing specifications for regeneration delay, for free-growing, and for procedural detail around the management of soils, riparian areas, and watersheds. The consequence of approaching it in this way is that less attention tends to go into defining what should be achieved overall; for instance, what future forest landscape characteristics should be created, and what water quantity and quality attributes from the watershed and what forest structure and composition are needed over time and space within a given area? More attention tends to be focused on achieving the rules and procedures.

Now, I am not here to judge the appropriateness of administrative- versus results-oriented approaches. If you examine other jurisdictions you will likely not encounter an objectives or results-based Code only, but a spectrum of plans, rules, results, and objectives with the emphasis weighted in one direction or the other. For example, more planning may be needed if results cannot be clearly defined. Some rules will remain if risks and uncertainties exist which the landowner is not prepared to carry.

In contrast to the administrative model, a results-based approach entails a very different philosophy. Here, attention shifts to defining, in advance, what the outcomes of management are supposed to achieve. And, unfortunately, this is a more difficult task than it might appear. Just think for a moment about green-up, block-size, and adjacency rules—

- what forest-level outcomes are we trying to achieve?
- under what circumstances should something else be considered? and
- how would we measure the efficacy of the alternative action?

The results-based approach to green-up will have to clarify outcomes for the full range of related values including hydrology, habitat, soil stability, visual impacts, and more.

We can ask similar tough questions about other rules, but the challenge will be to establish confidence in their replacement with—

- a set of clearly specified outcomes,
- innovative management approaches that will achieve these outcomes better or more efficiently; and
- ways of measuring success and managing risks along the way.

. . . a tough challenge, but one where science must play a crucial role in supporting all three areas.

Being a member of the science-providing community, it is probably not surprising that I see a great deal of future significance attached to our work.

Right now we see increasing demands to manage differently in order to achieve more social and economic benefits from our resources, and to address the increasing complexity of decision making. Both the public and the marketplace are calling for scientific validation of forest practices and for confirmation of sustainability.

I think it is inevitable that meeting these demands will invoke a new vision of forest management, with an opportunity for a more prominent role for science. It should not be taken for granted: we have to work hard to maintain the social trust in science.

Social considerations are definitely increasing in importance, but in a global context our future must surely lie in a knowledge-centred, innovation-based approach to all aspects of the forestry business—from growing and managing the forest for various uses, to harvesting, manufacturing, and marketing of timber products. Only in this way can we make best use of our resources, compete successfully in the marketplace, and achieve community objectives across the province. Decisions will be needed that make the best use of the available information with a heavy reliance on informed judgement. And, perhaps most importantly, decisions must be viewed as experiments, subject to constant testing as part of adaptive learning.

In the context of this vision, I'd expect that further shifts in the direction of results-based forestry are likely to occur. A results-based approach implies more latitude for licensees to select the most cost-effective method of implementation, while still achieving the desired outcome. So, inherently, we would expect this to increase the demand for knowledge. We would expect licensees to ask science providers for help in defining the range of possible outcomes, the alternative pathways to achieve them, and the risks associated with data uncertainties. I also expect that the public, and government regulators, will also be asking for help in defining outcomes in a scientifically rigorous manner. How, otherwise, can their achievements be measured in a way that ensures credible performance?

How far or fast we move to results-based management, and for what specific aspects of forestry, remains to be seen. Successful outcomes will depend upon a number of factors.

Moving to a results-based model requires clarity and acceptance regarding the results to be achieved, as well as a degree of comfort around the risks to be managed. We tend to be closest to achieving this where land-use planning processes are furthest advanced. It also will help to have a good sense of community support, First Nations consultation, stakeholder involvement, demonstrated licensee performance, and solid interministry working relationships. Also, confidence will be higher about choosing the means by which to achieve results, if those choices are made scientifically and are professionally accountable.

A more results-based approach is one of several key issues coming forward under the current Forest Policy Review and is linked to a number of factors, especially land-use planning, tenure reform, stumpage, and the Forest Practices Code. Within this array, decisions are required on which specific aspects will become results-based, and how these changes will be scheduled.

Implementing a results-based model could be facilitated through a commitment to real adaptive management (not just the short-term "garden variety" kind).

This approach to applied science can build confidence in areas where we do not have conclusive knowledge and experience, and can help to manage the risks associated with a results-based approach. Scientists have an important role here, in working closely with field clients to come up with appropriate designs for monitoring, analysis, and reporting. I hasten to add that while adaptive management is an important tool for achieving a science-to-management transition, it is not a panacea. We need those well-designed and monitored long-term installations in the background as well, to provide regular insight into how our complex ecosystems function over time.

I have given you some of my perspectives on the factors that could play a significant role in driving the demand for forest science, including a more result-based approach to forest management. I would now like to outline some of the very sobering challenges in responding to those demands.

At a time when science is needed as a foundation for the future of forest management and the forest products sector, science investment is in decline. British Columbia and Canada lag far behind other major wood-producing nations in the level of science and technology investment relative to forest sector GDP. Can we out-compete others on this basis? Can we demonstrate to others that sustainable forest management is being practiced if the commitment to understanding our complex ecosystems is unstable and declining?

Competitiveness also depends on being able to supply what the market wants at the right price. Being able to shift from commodity to customized forest products, and harvesting in a land base with physiographic challenges and resource protection requirements, all requires information, knowledge application, and creativity—and, of course, science.

What we have been discussing today is a results-based approach to management that will drive the demands for science to new levels, seriously stressing our ability to meet those demands. Being the consummate optimist that I am, however, I believe that British Columbia's forest sector is starting to take greater interest once again in the importance of science and technology as a key ingredient for future success. The consequences of maintaining the status quo are simply too disastrous to contemplate. The Committee of Forest Research Agencies of British Columbia, working in partnership with forest-sector client representatives, is taking the initiative of developing a workable science strategy and securing long-term commitments and funding.

Assuming that our capability to undertake good science is restored, some major challenges still exist in moving this science into management applications. Researchers and land managers work in different cultures and often have different training and experience. Characteristics of the research culture include: longer time horizons, freedom of inquiry, and findings heavily qualified and expressed with confidence limits. Characteristics of the management culture include: tight time frames, a desire for closure not probabilities, science as one of several factors which influence a decision, risk management, contentious decision-making environment, and public involvement. Understanding these cultural characteristics is central to building bridges that will enable effective communications and working relationships.

I am sure that the various workshops during the forum will provoke a lot of discussion on this topic. I really hope that we can make progress because some dysfunction is evident that may impede both management and the science community. In my view, the key is a close working relationship and friendship to facilitate mutual understanding. This brings out the best ideas and trust in implementing them.

In the real world of competing priorities and human nature, a results-based approach to forest management may progress slowly. Our old ways of doing business can seem deeply entrenched and difficult to displace, regardless of how outmoded they may be. We may also feel deeply challenged by the occasional frustrations of transferring scientific findings into the management arena or trying to pin those wily scientists down when decisions have to be made "yesterday." This forum provides a really critical step in the journey of science to management and I would like to congratulate the Partnership in taking the initiative.

AUTHOR

* ***Correspondence to:*** **Henry J. Benskin**, Director, Research Branch, B.C. Ministry of Forests, 712 Yates Street, Victoria, BC V8W 1L4.
E-mail: Henry.Benskin@gems5.gov.bc.ca

Identifying specific indicators of sustainable forest management

R.A. LAUTENSCHLAGER*

INTRODUCTION

The foundation of sustainable forest management (SFM) is the *integration* of social and ecological concerns and knowledge ("specifics") to direct management *at that time*. The Canadian Council of Forest Ministers has provided a "criteria and indicators" framework for SFM; however, the criteria and critical elements identified lack integration and seem most appropriate at broad scales. Natural resource managers, environmental interest groups, and public agencies need identifiable, measurable indicators of SFM that are integrated and appropriate at broad scales, as well as at a variety of finer scales. Previously, I have argued that if we hope to contribute to responsible natural resource use and address the most pressing environmental concerns, we must *identify the specifics*. That is, we must identify the specific environmental resource issues, which most commonly include:

- resources of concern;
- management practices that cause concern(s); or
- ecosystems in which resources and management practices are a concern (Lautenschlager 1996, 1998).

In addition, I have proposed that local (ecodistrict or smaller) "experts" could help by developing an integrated set of local natural resource concerns (social/ecological) associated with management practices and ecosystems to form a concern matrix.

THE "IDENTIFY-THE-SPECIFICS" APPROACH

Identifying what to monitor when assessing sustainability was easier when management favoured one or a few animal or plant species over a limited area. Contemporary calls to integrate and manage for several, if not all, environmental components, across scales, makes identifying where to start dramatically more difficult. Various, primarily, science-driven approaches have been proposed (Lautenschlager 1998), but few have been tested (Harms 1994). The identify-the-specifics approach:

- relies on, and seeks to integrate, local knowledge through broad-scale social or ecological "experts" (e.g., naturalists, natives, hunters, politicians, trappers, foresters, and the interested public) to establish the environmental base;
- starts from the premise that most environmental concerns are associated with concerns about specific management practices; and

CITATION —

Lautenschlager, R.A. 2000. Identifying specific indicators of sustainable forest management. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 7–9.

- leads to the development of concern matrices that identify and prioritize concerns at local and increasingly broader scales.

Local "experts" with experiential (social and ecological) knowledge and environmental interests, who represent ecosections, ecodistricts, or ecoregions (depending on the detail required), start this process by identifying and prioritizing the following local concerns.

1. Resource(s): Often a species or species group (guild), but may include biotic community, abiotic components (water, aggregates, etc.), biotic or abiotic processes, and cultural or spiritual values. Not required, but potentially helpful, would be specific resource concerns. These are commonly related to reduced abundance or reproductive output, but could include an ecological process or general concern.
2. Management: The management associated with the specific resource of concern (e.g., fire suppression, hunting, a silvicultural system, etc.), or an environmental change(s) caused by this management.
3. Ecosystem: In what ecosystem(s) is management commonly affecting this resource (e.g., riparian zones, high-elevation spruce/fir forests, etc.).

To date, experts who have participated in this exercise prefer to present generalities as opposed to specifics; however, when directed, valuable specifics were identified (Lautenschlager et al. 2000). The value of the "specifics" approach is enhanced when experts identify, and then collectively prioritize, specifics. (Although getting "experts" to agree on priorities may not be easy, consensus should be sought.)

Reviews, additions, and adjustments at each scale are based on input from knowledgeable experts from the next broader scale (ecoregion, ecozone, etc.) who have an altruistic interest in the long-term sustainability of natural resources throughout the area of interest. Including an appropriate mix of experts in discussions at all scales should ensure that both the public and political leaders accept the legitimacy and value of the priorities (indicators) identified. In addition, natural resource management agencies must truly consider the "greater good" rather than short-term economic and special-use interests. Priorities and measures of sustainability at every scale are based on feedback from the scale above. This includes recognized commonalties in resources, management practices, and ecosystems of concern from the ranked priority matrices of the scales in question.

As local concern matrices are built and adjusted, it may become obvious that specific resource concerns, or groups of concerns, are consistently associated with specific management practices or ecosystem types across a large geographical area. Or it may become obvious that, regardless of the specific resource, a particular management practice becomes a problem only when implemented in a specific ecosystem type. If so, conclusions based on these matrices could become the focus for socially and ecologically integrated indicators of SFM, as well as the effects of alternative management practices on these indicators.

When completing natural resource concern priority matrices at any scale, it is important to be as specific as possible and to identify accurately the resource(s) and associated management practices of concern. For instance, "neotropical migrant birds" would be an inappropriate concern at every scale. This entry is too broad to help identify local problems and their association with specific management practices. If several, specific, neotropical migrant species were entered, and the concern for each was population decline, then it might become clear, based on an understanding of their biology, that all required similar habitat or ecosystem types and that declines were associated with changes, management-related or successional, to critical habitats or ecosystems.

CONCLUSIONS

Ostrom (1990) argues that information from smaller organizational units is one key to developing larger organizational units that successfully manage larger "common pool" resources. The identify-the-specifics approach is based on this premise. The matrices developed provide the scale-appropriate social and ecological compass for moving toward sustainable forest management. Some have argued that we need to understand ecosystems, but that job will never be complete, and management continues. Therefore, the first priority is to identify and quantify the effects of specific management practices of concern on ecosystems through time so that inappropriate practices can be modified and alternatives developed and tested. Meaningful discussions, however, cannot begin until we have identified specific concerns. Saying that we support "biodiversity conservation," "ecological integrity," "forest health," or "sustainable forest management," will not help us identify interactions among the social needs, biota (or abiotic components), management practices, and ecosystems of greatest concern.

Identified specifics, once organized, provide the bridge from philosophical pronouncements to realistic goals and result in an integrated multiscale set of indicators of SFM appropriate for that time. Where we once discussed vague general goals, we may soon be discussing specific concerns, the management practices that lead to those concerns, or the ecosystems in which they occur. As soon as the specifics become clear, they may become appropriate indicators of SFM. Only then can we implement practices, ranging from active management to complete protection, that address concerns across various scales in an ecosystem context, and know what components to monitor to examine the effectiveness of management alternatives.

REFERENCES

Harms, R.R. 1994. Biological diversity: from conceptual framework to practical application. Wildlifer 263:34.

Lautenschlager, R.A. 1996. Identify the specifics: a biopolitical approach to establishing research priorities. Journal of Forestry 94(4):31–4.

_____. 1998. From rhetoric to reality: using specific environmental concerns to identify critical sustainability issues. Ecosystems 1(2):176–82.

Lautenschlager, R.A., H. MacLeod, C. Hollstedt, and D. Balsillie. [2000]. Examining the "specifics" approach to identify local indicators of sustainable natural resource management in central and western Canada. In preparation.

Ostrom, E. 1990. Governing the commons: the evolution of institutions for collective action. Cambridge University Press, New York, N.Y.

AUTHOR

* ***Correspondence to:*** R.A. Lautenschlager, Ontario Ministry of Natural Resources at the Ontario Forest Research Institute, 1235 Queen Street East, Sault Ste. Marie, ON P6A 2E5.

E-mail: r.a.lautenschlager@mnr.gov.on.ca

Forest resource research in the Cariboo Forest Region

JANE PERRY*, KEN SONEFF†, AND CLAIRE TRETHEWEY‡

INTRODUCTION

The investigation of important forest resource management issues is documented in a list of 342 projects that include scientific experiments, operational trials, and monitoring. Most of the projects, particularly the newer ones, engage a team of scientists and practitioners to clearly define a complex operational resource management issue and to test options from which successful results can be applied in the field.

Challenges for forestry research in the Cariboo Region include—

- Implementation of higher-level plans: technical assistance from research staff and initiation of trials to resolve operational issues.
- Results-based Forest Practices Code: research to define desired end results with extension to practitioners.
- Forest product certification: a range of research involvement, including defining standards and providing data on criteria and indicators.
- New technology: the use of geographical information systems (GIS), remote sensing, and new technological tools in forest management.
- First Nations: studies, extension, training, and collaborative work on traditional use.
- Partnerships: SIFERP and NFREP (Northern Forest Research and Extension Partnership) are two examples.
- Stand management: mixedwood management and meeting biodiversity objectives.
- Forest health: detection methods, population monitoring, and modelling of attack levels for mountain pine beetle.
- Global warming: documenting changes in species ranges through monitoring and research.
- Framework for long-term research: committed, permanent funding for program stability.

INVESTMENTS

In 1999, we provided a summary of forest resource research projects in the Cariboo Forest Region. This synopsis was updated from a September 1998 summary and included information from: the Alex Fraser Research Forest at the University of British Columbia; the ministries of Forests and Environment, Lands and Parks; Lignum Ltd.; Simon Fraser University; and the Science Council of B.C. The summary lists 342 projects that are active or complete. Most trials include two or more agencies and at least two researchers. The list does not include undocumented operational trials and may exclude some individuals or agencies.

Citation —

Perry, J.L., K.W. Soneff, and C. Trethewey. 2000. Forest resource research in the Cariboo Forest Region. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 11–14.

A significant proportion of early research, begun in the mid-1970s, was conducted by the Ministry of Forests on aspects of reforestation, including stock types, site preparation, and microsite planting.

Research personnel in government and academic institutions tend to remain focused on specific studies for relatively long periods. An intangible, but real investment, is the expertise and commitment research personnel invest in established trials and in participating in new research.

TRENDS

The titles of the listed projects show that research design has shifted from a generally focused approach that investigates a discrete problem, to one that employs a multidisciplinary methodology. The investigators and the agencies involved bring a broad base of collective expertise. Most current research will be applied to solve field-based operational issues that require immediate application for resource management decision making.

Specific technical trends in forest resource research include:

- Adaptive management and operational-scale research: "learning from doing."
- Increased emphasis on extension to apply, share, and communicate information. The Southern Interior Forest Extension and Research Partnership and Northern Forest Research and Extension Partnership are helping to advance and formalize extension.
- Silvicultural systems, which provide alternative harvesting, regeneration, and tending practices, to increase options for those based on clearcutting.
- A reduction in new reforestation trials; to continue instead with older trials now producing valuable knowledge for operational application. Reforestation research is also being included more broadly under silvicultural systems.
- Biocontrol for forest health and vegetation management.
- Studies on biodiversity, with operational application of new knowledge, proposed in an Innovative Forest Practices Agreement (IFPA) forestry plan.

CHALLENGES

Challenges for forestry research in the Cariboo Forest Region include the following.

Implementation of Higher-level Plans

Implementing the Cariboo-Chilcotin Land Use Plan (CCLUP) has required technical input from government research and technical staff on strategies for biodiversity and key ungulate species. As well, some research trials were initiated to test the accommodation of multiple resource use, such as timber harvesting and habitat maintenance. Public attitudes about forest practices have changed, but changing practices also affect communities and local economies. Both ongoing and new research is required to find workable solutions.

Results-based Forest Practices Code

The administrative streamlining of the Forest Practices Code and the subsequent establishment of "results-based" pilot projects in late 1999 has increased reliance on professional decision making in planning and prescriptions. A results-based approach requires clearly defined and desired results for research to address, such as riparian management zone widths, wildlife tree patch area requirements, a free-growing definition, and stocking standards.

Practitioners require the technical results of research and operational trials for interpretation and application. Extension is, therefore, a critical component of a results-based Forest Practices Code.

Forest Product Certification

Research involvement in certification will include input and review for the development of certification standards. Within the standards, research information will be required for guidelines and conservation attributes, and to contribute an understanding of ecosystem functions and values. Further researchers, and research work, may be needed for monitoring and assessment, including data for specific criteria and indicators.

New Technology

The development, use, and refinement of new technology for application in a wide range of forest management activities is a growing issue in resource management. GIS applications, remote sensing, and high technology tools in all aspects of forest planning and management are increasing in significance. Examples include remote sensing to detect and map forest health concerns, visual quality modelling, and the use of GIS in resource management planning.

Additionally, technology generally reduces the labour required for a given task. Technological application must be co-ordinated with various employment measures to maintain employment and a well-trained workforce.

First Nations

With the legal requirement to protect archaeological and traditional use values in forest resource management and planning activities, traditional knowledge is becoming increasingly valued. Traditional use studies, training, extension, and collaborative efforts are helping to address gaps in understanding. Research staff, particularly botanists, may be called to confirm the presence of culturally important sites through confirmation of key plant species.

Partnerships

Partnerships among research agencies, First Nations, government agencies, industry, and communities are a growing aspect of resource-based research. These partners ensure that research design incorporates all necessary factors and that the application of results will be suitable for the intended users.

Stand Management

Mixedwood and non-conifer management provides options to achieve biodiversity objectives and apply ecosystem management concepts. Research trials on riparian and soil restoration projects are helping to maintain forest productivity.

Forest Health

The recent rapid rise in populations of mountain pine beetle requires detection methods, population monitoring, and modelling of attack.

Global Warming

Global warming will gradually shift tree ranges to produce off-site trees from formerly site-adapted genotypes. The reactions of insects and pathogens to stressed trees will likely produce increased forest health challenges. The reinstatement of biologically based forest health surveys to supplement operational surveys is important to accurately monitor projected changes in forest health conditions.

Framework for Long-term Research

As government-funded forest resource research currently heads for another projected decline, alternative mechanisms for forestry research are required. Research investment needs facilitation through new means, possibly including increased security of tenure for major licensees to merit such investment.

AUTHORS

* ***Correspondence to:*** Jane Perry, RR #1, Box 17 Esler and Kallyn, Williams Lake, BC V2G 2P1.
E-mail: jperry@wlake.com

† Research Manager, B.C. Ministry of Forests, Cariboo Region
‡ University of British Columbia, Alex Fraser Research Forest

From the individual to the organization: Our cultural roots affect our decisions

ANN SCHAUBER*

INTRODUCTION

As professionals in organizations grapple with the wise management of resources, an understanding of how one's cultural roots affect decisions is the first step to including a broader range of perspectives in effective decision making. Choosing multiple perspectives is an essential intercultural skill, which leads to more creative and powerful decision making. In this presentation, I synthesize the literature in the areas of intercultural communication, organizational management, and intergroup relations.

DISCUSSION

All people have a culture, which is often just outside conscious awareness. The term "culture" refers to a set of cognitive, affective, and behavioural patterns shared by a group of people (Hall 1959). Some of the many dimensions of culture include age, gender, ethnicity, race, education, and income (Loden and Rosener 1991). People from different cultural groups have different perspectives, manifested in their values, attitudes, beliefs, and behaviours. Numerous studies specifically describe these differences (Kluckhohn 1961; Hall 1983; Hofstede 1991; Triandis 1995). Core values and beliefs affect the decisions that people make. What the decision is, however, may differ depending on a person's value orientation.

Bringing one's own culture into conscious awareness is the first step toward building an organization that is inclusive of multiple perspectives. The people inside an effective, culturally diverse organization come from diverse cultural backgrounds and have a "voice" in the organization. Such an organization includes multiple perspectives on issues and ideas, and makes decisions based on the common purpose of the organization (Cox 1994).

The first step toward more inclusive decision making in organizations is to become aware of oneself as a "cultural self" and then to bring one's cultural beliefs, values, and assumptions into conscious awareness. The next step is to become aware of the cultural values, beliefs, and assumptions of others. The third step is to develop and apply a set of skills that allows group members from differing cultures to communicate effectively. An effective organizational decision is one in which the voices of all the cultures represented are heard and respected. Each cultural group still maintains the integrity of their own culture. It is in the "coming together" that a third culture is formed for the purpose of the management decision.

Citation —

Schauber, A.C. 2000. From the individual to the organization: our cultural roots affect our decisions. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 15–16.

REFERENCES

Cox, T. 1994. Cultural diversity in organizations: theory, research, and practice. Berrett-Koehler, San Francisco, Calif.

Hall, E.T. 1959. The silent language. Doubleday, New York, N.Y.

_____. 1983. The dance of life. Doubleday, New York, N.Y.

Hofstede, G. 1997. Cultures and organizations: software of the mind. McGraw-Hill, New York, N.Y.

Kluckhohn, F. and F. Strodtbeck. 1961. Variations in value orientations. Row and Peterson, Evanston, Ill.

Loden, M. and J.B. Rosener. 1991. Workforce America! Managing employee diversity as a vital resource. Business One Irwin, Homewood, Ill.

Triandis, H. 1995. Individualism and collectivism. Westview Press, Boulder, Colo.

AUTHOR

* ***Correspondence to:*** **Ann C. Schauber**, Oregon State University, 307 Ballard Hall, Corvallis, Oregon 97331-3602 USA.

E-mail: ann.schauber@orst.edu

Achieving a globally competitive industry: Using science, innovation, and best available knowledge

BILL BOURGEOIS*

INTRODUCTION

For the province's forest industry to become globally competitive, companies must produce a quality product at a competitive price. Excellent service in the sale of the product and other services to the customer are also required. These are the traditional components of corporate competitiveness. Additionally, forest sector companies must demonstrate that their forest management practices are socially acceptable. This requirement is not local or provincial in nature, but international. Customers in many parts of the world have increasingly pressured companies to protect environmental and social values, as well as provide quality products and services. The use of science, innovation, and best available knowledge is essential in addressing two of the important requirements for a competitive industry; that is, socially acceptable forest management practices and competitive prices.

SOCIALLY ACCEPTABLE PRACTICES

In general, socially acceptable practices are part of sustainable forest management. This involves the balancing of environmental, social, and economic values so that environmental and economic sustainability and community stability are achieved.

In a specific forest management unit, sustainable forest management requires that you:

- define the forest management area;
- identify the objectives for each of the management components;
- develop and integrate strategic, tactical, and operational plans;
- provide and use updated resource inventories in plans;
- conduct forest practices that lead to meeting sustainable forest management objectives;
- analyze the impacts, both positive and negative, of forest practices on resource values;
- collect research and monitor data for use in evaluating practices; and
- use new data when applying adaptive management to plans and practices.

It is one thing for a company to announce that it is practicing sustainable forest management and another for that statement to be accepted. The public does not trust the statements of industry. A third-party evaluation will be required. Who are the trusted third parties? When posing this question to focus groups, they tend to answer "moderate environmental groups with an international presence." Each company could obtain third-party evaluation from one or more groups, or use a system endorsed by several environmental groups. This latter approach is reflected when certification is obtained through an

Citation —

Bourgeois, B. 2000. Achieving a globally competitive industry: using science, innovation, and best available knowledge. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 17–18.

internationally recognized system such as the Forest Stewardship Council. Although achieving certification provides the documented "proof" that a company is moving towards sustainable forest management, it is wise to communicate this and other achievements to the public at regular intervals.

COMPETITIVE PRICES

Operational constraints and stumpage are the two critical factors in cost-competitive forest management. Clearly, the operational constraints must meet sustainable forest management objectives; however, we do have some unique conditions in the province compared to other jurisdictions. We also do not know as much as we would like to about the effects of forest practices on non-timber resources. Therefore, while a precautionary approach should be taken, this should not become ultraconservative.

Stumpage payments constitute a high cost of operations in British Columbia. The stumpage system must balance both the provincial need for economic rent and the objective of maintaining a competitive industry. Add to this the unique trade situation with our major customer, the United States, and the associated Softwood Agreement. We, therefore, need a stumpage system that reflects the ability to pay, the market price of the product, and the operating conditions. It should also encourage reinvestment in the forest for long-term stability. This is very complicated and not an easy task.

CHALLENGES

Using science, innovation, and best available knowledge will clearly be critical if we are to meet sustainable forest management requirements, provide validation for sustainable management, and apply cost-effective operating constraints. To realize this objective, we must:

- think "outside the box";
- develop strategic, tactical, and operational plans;
- insist on maintenance of a long-term provincial forest management funding source;
- incorporate the acquisition and application of research and monitoring results into the forest management philosophy of government and companies;
- use the knowledge we have today;
- become certified by one or more internationally accepted systems;
- work more co-operatively with government, industry and environmental organizations to meet sustainable forest management objectives and reduce costs; and
- revise the stumpage system.

To meet these challenges, people must take risks, learn how to manage change, and work co-operatively. This is very possible, and I look forward to working with people who want to create and demonstrate success.

AUTHOR

* ***Correspondence to:*** **Bill Bourgeois**, Vice President, Forest Policy, Lignum Limited, Suite 1200, 1090 West Georgia Street, Vancouver, BC V6E 3V7.

E-mail: wwb@lignum.com

Effectiveness of repeated manual cutting of mixed shrub vegetation in an Interior Cedar–Hemlock zone spruce plantation: Fifth-year results

PHILIP COMEAU* AND BALVINDER BIRING†

INTRODUCTION

During 1995, manual treatments were applied to 38 000 ha in British Columbia, at a cost of $20 million. This represented 57% of the area brushed, and 66% of brushing expenditures (B.C. Ministry of Forests 1997). In 1995, 93% of the area brushed the Nelson Forest Region was treated manually.

Because non-crop vegetation resprouts, repeated brushing of the same site may be necessary. Whitehead (1989) found that a single cutting of thimbleberry, raspberry, and fireweed provided limited, short-term vegetation control. LePage et al. (1991) reported that thimbleberry cover returned to pre-treatment levels within 1 year following cutting. In contrast, both of these studies report that glyphosate application controlled all species for at least 3 years. Comeau (1992 A, B, C) reported that cutting repeated over a 4-year period significantly reduced cover and height of vegetation in communities composed of fireweed, ladyfern, bracken, and thimbleberry. At two of three study sites, diameter of spruce seedlings was also significantly increased by repeated cutting treatments.

METHODS

In 1992 we initiated a study to examine the effectiveness of repeated cutting for controlling vegetation in a mixed shrub-herb community to release planted Engelmann spruce (*Picea engelmannii* Parry) seedlings. The study site is located at Soards Creek near Mica, B.C. in the Interior Cedar–Hemlock very wet cool biogeoclimatic subzone (ICHvk). The site was harvested in 1983/84, broadcast burned in October 1984, and planted in June 1985. Following plantation failure, the site was mechanically site prepared with an excavator in August, 1990 and Engelmann spruce (1+0 PSB 415B) seedlings were planted in June, 1991.

Eight treatments were compared:

1. cutting once in spring of 1992;
2. cutting once in summer of 1992;
3. 3 years of cutting once annually in the spring (mid- to late June) starting in 1992;
4. 3 years of cutting once annually in the summer (late July) starting in 1992;
5. 3 years of cutting twice annually in the spring and in the summer starting in 1992;

CITATION —

Comeau, P. and B. Biring. 2000. Effectiveness of repeated manual cutting of mixed shrub vegetation in an Interior Cedar–Hemlock zone spruce plantation: fifth-year results. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 19–22.

6. 2 years of cutting twice annually in the spring and in the summer starting in 1993;
7. applying glyphosate herbicide at 2.1 kg ai/ha during late August, 1992; and
8. an untreated control.

Treatments were replicated three times in 30 × 30-m plots.

Within each treatment plot, 20 spruce seedlings were measured during the fall of each year from 1991 to 1996. Vegetation percent cover and modal height was recorded within a 1.26 m radius plot centred on each of 10 crop seedlings in each treatment plot during the summer (July) of 1992, 1993, 1994, 1995, and 1996.

RESULTS

Vegetation Response

Repeated cutting for 3 years and glyphosate application in August 1992 resulted in reductions in total vegetation cover for 3 years. However, no significant ($p > 0.05$) differences in total cover were detected among treatments in 1995 or 1996 because of revegetation growth.

Treatments had a significant ($p \leq 0.05$) effect on vegetation height in 1993, 1994, and 1995. In the summer of 1995, the glyphosate treatment (7) and all repeated manual cutting treatments (3, 4, 5, and 6) resulted in significant reductions in vegetation height over those found in the control plots. In 1996 (year 5), no significant differences in vegetation height were detected.

Spruce Seedling Response

Survival at the end of 5 years was high in both treated (more than 90%) and untreated (control) plots (86%). Treatments had no significant effect on spruce survival 5 years after treatment (Table 1). Competition was never severe, except in localized portions of the study area.

Glyphosate application (treatment 7) and repeated cutting (annually or twice a year) (treatments 3, 4, 5, and 6) resulted in spruce seedlings with significantly larger root collar diameter than untreated seedlings at the end of 5 years. Treatments 1 and 2 resulted in intermediate values of root collar diameter that did not differ significantly from untreated seedlings (8).

Repeated summer cutting (treatment 4) significantly increased fifth-year height over that of untreated seedlings (8) and seedlings which only received a single summer manual treatment (treatment 2). However, no significant differences were detected between any of the cutting treatments and the glyphosate treatment.

CONCLUSIONS

Results from this study suggest:

- a single manual treatment is unlikely to benefit seedling growth in a mixed shrub community;
- repeated cutting of vegetation (for 2–3 years) resulted in spruce diameter growth (5 years after the start of treatments) that is equal to that of a single application of glyphosate herbicide; and
- repeated manual cutting in midsummer (for 3 years) resulted in a 31% (28 cm) increase in seedling height at the end of 5 years, which is equivalent to approximately 1 year growth at age 5.

TABLE 1 *Fifth-year (October 1996) means of seedling measurement data and vegetation (July 1996) data*[a]

Treatment	Root collar diameter (mm)	Height (cm)	H:D[b] ratio	Survival (%)[c]	Vegetation % cover	Modal height (cm)
1: Spring 1992						
[1 cutting]	23.4abc	102.6ab	44.9ab	90.0	79.9	105.4
	(2.7)	(12.1)	(3.7)	(7.6)	(18.2)	(65.8)
2: Summer 1992						
[1 cutting]	21.2bc	89.7b	44.3ab	93.3	82.8	81.1
	(1.1)	(3.8)	(0.8)	(3.3)	(2.4)	(26.6)
3: Spring 1992+						
[3 years of cutting 1×/year]	27.0ab	105.6ab	39.9b	100.0	89.9	66.3
	(1.6)	(8.4)	(0.5)	(0)	(17.8)	(16.9)
4: Summer 1992+						
[3 years of cutting 1×/year]	29.4a	118.1a	41.1b	95.0	78.7	106.1
	(1.3)	(5.0)	(0.5)	(0)	(5.3)	(56.3)
5: Spring/summer 1992+						
[3 years of cutting 2×/year]	29.4a	115.7ab	39.7b	96.7	76.0	70.5
	(0.3)	(4.9)	(1.6)	(3.3)	(16.0)	(7.3)
6: Spring/summer 1993+						
[2 years of cutting 2×/year]	27.4ab	110.7ab	41.7b	93.3	95.3	82.9
	(1.3)	(6.1)	(0.5)	(4.4)	(3.0)	(12.2)
7: Glyphosate						
[2.1 kg ai/ha]	27.5ab	109.8ab	41.6b	96.7	60.1	62.8
	(1.3)	(3.6)	(1.6)	(1.7)	(2.6)	(10.6)
8: Control	19.1c	90.2b	49.2a	86.0	102.3	100.4
	(1.8)	(5.8)	(1.2)	(1.7)	(7.0)	(7.8)
p-value for test of overall treatment effect	0.0016	0.00819	0.0120	0.3035	0.3566	0.2572

a N = 50–60 seedlings; standard error appears in parentheses. Letters indicate significant differences within columns between treatments detected using Tukey's Studentized Range Test at $p < 0.05$.
b H:D ratio = Height/root collar diameter.
c Survival = seedling survival (% of initial numbers).

ACKNOWLEDGEMENTS

Funding for this project has been provided by the Canada–British Columbia Partnership Agreement on Forest Resource Development (FRDA II) (Project BC-FR33) and Forest Renewal British Columbia (Project HQ96403-RE).

REFERENCES

Braumandl, T.F. and M.P. Curran. 1992. A field guide for site identification and interpretation for the Nelson Forest Region. B.C. Ministry of Forests, Nelson, B.C. Land Management Handbook No. 20.

B.C. Ministry of Forests. 1997. Annual Report of the Ministry of Forests for the fiscal year ended March 31, 1996. B.C. Ministry of Forests, Victoria, B.C.

Comeau, P.G. 1992A. Expert Committee on Weeds, Research Report, Western Canada Section Meeting, Dec 1–3, 1992, Winnipeg, Man., Vol. 2:1081.

_____. 1992B. Expert Committee on Weeds, Research Report, Western Canada Section Meeting, Dec 1–3, 1992, Winnipeg, Man., Vol. 2:1081.

_____. 1992C. Expert Committee on Weeds, Research Report, Western Canada Section Meeting, Dec 1–3, 1992, Winnipeg, Man., Vol. 2:1082.

LePage, P., J.C. Pollack, and K.D. Coates. 1991. Chemical and manual control of thimbleberry (*Rubus parviflorus*) in northwestern B.C.: rate and timing trial. Western Journal of Applied Forestry 6(4):99–102.

Whitehead, R. 1989. Expert Committee on Weeds (ECW) Research Report. Western Canada Section Meeting, Nov. 28–30 1989, Banff, Alberta. Volume 3:222.

AUTHORS

* ***Correspondence to:*** **Philip G. Comeau**, B.C. Ministry of Forests, Research Branch, PO Box 9519 Stn Prov Govt, Victoria, BC V8W 9C2.

E-mail: Phil.Comeau@gems2.gov.bc.ca

† B.C. Ministry of Forests, Research Branch

Armillaria root disease: A major impediment to sustainable management of southern Interior ecosystems

DUNCAN MORRISON*

INTRODUCTION

Armillaria ostoyae (Romagn.) Herink has a circumpolar distribution in the northern hemisphere where it causes Armillaria root disease of conifers (Kile et al. 1991). In British Columbia, the fungus occurs south of a line between McBride and Bella Coola, and in the Interior it is found in most biogeoclimatic subzones, except those that are very dry and above the elevational limit. Within its range, it attacks all species of trees, many shrubs, and some herbs. Tree mortality usually begins 5–7 years after stand establishment and can continue throughout a rotation.

In managed forests infested by Armillaria root disease, the stump and root system of cut trees have an essential role in disease development. In thinned (Cruickshank et al. 1997), selectively cut (Shaw et al. 1976), and clearcut (Woods 1994) stands, the stump and root system of cut, infected trees can be colonized and become inoculum. Inoculum is woody substrate containing *A. ostoyae*, and inoculum potential is a measure of the fungus' energy. Increases in the amount and potential of inoculum put residual trees and regeneration at risk from Armillaria root disease.

Some results are reported here from two studies on the epidemiology of Armillaria root disease, one on juvenile stands and the other on mature stands, parts of which had been selectively cut. These studies had the following objectives.

- To determine the incidence of trees with above-ground symptoms and below-ground infection at sites in the dry, moist, and wet climatic regions.
- To observe the host–pathogen interaction at infections; that is, to observe whether the fungus was advancing (progressive) or had been stopped (callused).
- To measure the effects of selective cutting in mature stands on below-ground incidence of infected trees and on merchantable volume in five tree-condition classes.

METHODS

Five sites with 12–24-year-old plantations, or naturally regenerated stands, were selected from among candidates in each of the dry, moist, and wet climatic regions of the Nelson Forest Region. Plots (0.01 ha) were centred on trees killed by *A. ostoyae* more than 5 years or less than 2 years previously, or where there were no symptomatic trees. In two mature stands approximately 100 years old (one in the IDFdm2, the other in the ICHmw2), five plots of 0.04 ha were located in parts of the stands that were undisturbed

Citation —

Morrison D.J. 2000. Armillaria root disease: A major impediment to sustainable management of southern Interior ecosystems. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 23–26.

or had been selectively cut 30 and 13 years previously, respectively. Merchantable volumes in five tree-condition classes were determined using the Ministry of Forests cruise compilation program. All trees in plots were examined for above-ground symptoms of Armillaria root disease before being removed from the soil by an excavator. Root systems were examined for infections, and infections were classified as callused or progressive. Data were analyzed using the SAS statistical package, including logistic regression, ANOVA, Student Neuman-Keuls test, and *t*-tests.

RESULTS AND DISCUSSION

In juvenile stands, significant differences were found in the percentage of trees with below-ground infection among climatic regions ($p < 0.0001$), with values for dry region sites being significantly lower than those in the moist and wet regions. Below-ground incidence was significantly greater ($p < 0001$) in plots centred on a dead tree than in asymptomatic plots. Significant differences ($p = 0.01$) were evident among climatic regions in the percentage of trees with below-ground infection that showed above-ground symptoms. In the dry region, 51% of trees infected below ground were detected compared to 28% and 23% in the moist and wet regions, respectively. The probability of a tree being infected below ground increases with DBH and is higher in the moist climatic region than in the wet or dry regions (Figure 1).

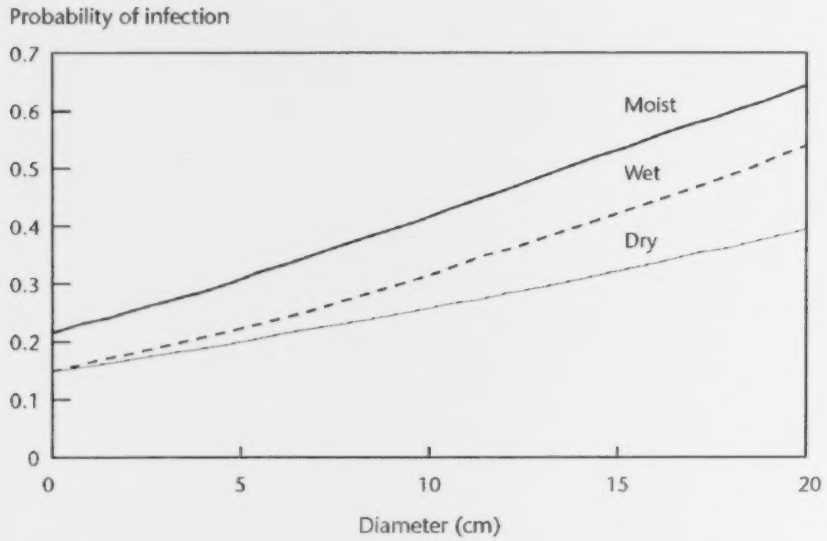

FIGURE 1 *Probability of below-ground infection on juvenile coniferous trees up to 20 cm DBH at sites in the dry, moist, and wet climatic regions.*

In the moist and wet regions, about 55% of infected trees had at least one progressive infection compared to 78% in the dry region; on more than 80% of these trees in all climatic regions, the progressive infection was at or within 50 cm of the root collar. Therefore, many infected trees are at risk of being killed by *A. ostoyae* in the future. Although it is encouraging that about 45% of infected trees have stopped the spread of the fungus, the disease has not become quiescent. Cruickshank et al. (1997) showed that cutting of infected trees during thinning resulted in colonization of the stump and spread

of *A. ostoyae* to adjacent crop trees via root contacts. Thinning could increase the proportion of infected trees in juvenile stands and result in mortality.

In undisturbed parts of the two mature stands, below-ground incidence of infected trees was 10% at the dry site and 80% at the moist site. At the dry site, 27% of trees with below-ground infection showed above-ground symptoms compared to 15% at the moist site. The probability of a tree being infected below ground increased with DBH (Figure 2), as it did in the juvenile stands.

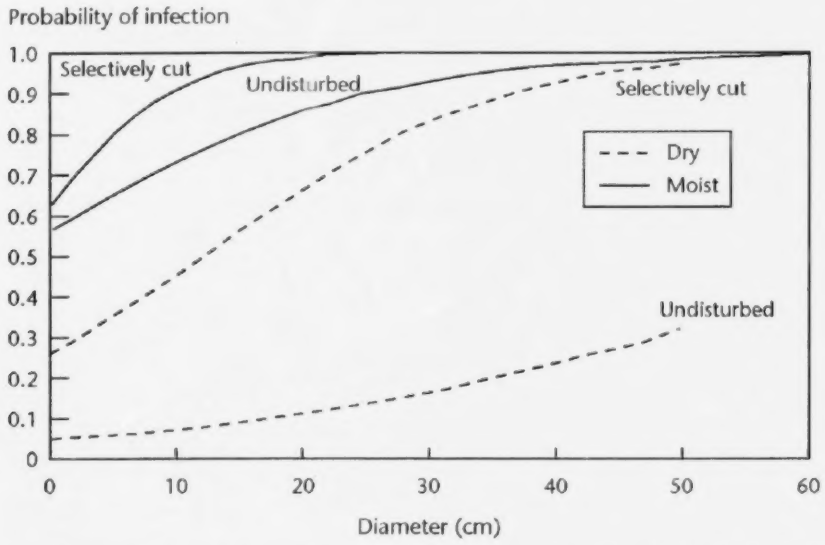

FIGURE 2 *Probability of below-ground infection on mature conifers in undisturbed and selectively cut parts of stands in the dry and moist climatic regions.*

Selective cutting significantly increased the probability of infection at the dry site ($p = 0.0001$), but not at the moist site ($p = 0.91$). At the dry site, about 95% of infected trees had one or more progressive infections compared to 75–80% at the moist site; differences between undisturbed and selectively cut plots were not significant. At the dry and moist sites, 55% and 100%, respectively, of the stumps created by the selective cut were colonized by *A. ostoyae*. In selectively cut plots at both sites, a significant decrease was evident in the percentage of merchantable volume in the uninfected condition class compared to that in undisturbed plots. Increases also occurred in the percentage of volume in the *A. ostoyae*-killed, -threatened, and non-threatened classes.

In summary:

- Climate affects incidence of infected trees, symptom expression, and host response.
- Only one-quarter to one-half of infected trees at dry sites and one-sixth to one-quarter at moist sites show above-ground symptoms.
- Probability of infection by *A. ostoyae* increases with increasing DBH.
- Pre-commercial thinning may increase inoculum to a level that results in killing of crop trees.
- Selective cutting increases the amount and potential of *A. ostoyae* inoculum resulting in an increase in incidence of infected trees and mortality. The increases are greater in the dry region. Damage may not become obvious until 20–30 years after harvest.

Is Armillaria root disease a threat to sustainable management in the southern Interior? The results of

these studies suggest that this is the case. The threat can be reduced by modifying practices to minimize the amount of inoculum created or by mechanical removal of potential inoculum during thinning and selective harvesting.

REFERENCES

Cruickshank, M.G., D.J. Morrison, and Z.K. Punja. 1997. Incidence of Armillaria species in precommercial thinning stumps and spread of *Armillaria ostoyae* to adjacent Douglas-fir trees. Canadian Journal of Forestry Research 27:481–90.

Kile, G.A., G.I. McDonald, and J.W. Byler. 1991. Ecology and disease in natural forests. *In* Armillaria root disease. C.G. Shaw and G.A. Kile (editors). U.S. Department of Agriculture Forest Service, Washington, DC. Handbook No. 691. pp. 102–21.

Shaw, C.G., L.F. Roth, L. Rolph, and J. Hunt. 1976. Dynamics of pine and pathogen as they relate to damage in a forest attacked by Armillaria. Plant Disease Reporter 60:214–8.

Woods, A.J. 1994. The behaviour and impacts of *Armillaria ostoyae* in mature stands and plantations in the Shuswap region of British Columbia. MSc thesis. University of British Columbia, Vancouver, B.C.

AUTHOR

* ***Correspondence to:*** **Duncan J. Morrison**, Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, 506 West Burnside Road, Victoria, BC V8Z 1M5.

E-mail: dmorrison@pfc.forestry.ca

Riparian management and stream temperature

PATRICK TETI*

INTRODUCTION

The scientific literature clearly shows that the summertime temperature of a stream in a temperate forested environment tends to increase after removal of riparian vegetation. In general, temperature increases are not a function of the amount of harvesting in a watershed, but rather are a function of the reduced level of shade provided by riparian vegetation. Both mathematical models and empirical observations indicate that temperature increases may be prevented as long as effective riparian buffers preserve stream shading. Effective buffers are those that maintain stream shading at close to natural levels, and that resist blowdown.

RIPARIAN BUFFERS

Riparian buffers are clearly capable of preventing alterations in stream temperature regimes. However, specifying riparian buffers in practice requires the weighing of costs and benefits in the absence of complete information. Returns diminish when buffers are wider than some optimum width or are further upstream from the target reach than some optimum distance. The uncertainty surrounding the ideal specifications for riparian buffers is partly encompassed by the questions "how wide" and "how far upstream."

Buffer width itself is only an indirect criterion for preserving shade. A fixed-width buffer on both sides of a stream is a simple specification, but the amount of shade this provides varies with factors such as stream orientation, topography, and the characteristics of native vegetation. When a stream has an east–west orientation, trees on the north side provide only a limited amount of shade at midday, and only if their branches overhang the water. Therefore, fixed-width buffers are not as efficient at minimizing stream temperature as are buffers designed to maximize the retention of shade. It is, therefore, more effective to think of "buffer design" than "buffer width."

MEASURING STREAM SHADE

Various methods are used to estimate the amount of shade provided to a stream by riparian vegetation. The most logical measurement recommended in the literature is of *angular canopy density*. This parameter is defined as the percent canopy along that portion of the sun's path between 10:00 A.M. and 2:00 P.M. (local solar time) in mid- to late summer as viewed from the water surface. Perhaps a simpler

Citation —

Teti, P. 2000. Riparian management and stream temperature. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 27–8.

definition is the "shade during the 4 hours at midday." This measurement is not yet in general use. Instead, shade is approximated by methods of unknown accuracy. Obviously, shade is highly variable along a stream's width and length, and any sampling procedure must consider this.

Methods are being developed to measure stream shade as angular canopy density at a point and to sample shade along a stream reach.

DOWNSTREAM EFFECTS

One of the most important findings in the literature is that the downstream thermal effects of harvesting on small, non-fish bearing streams may be small. Research in Washington State has shown that the cumulative temperature effects on third-order streams attributed to the harvesting-related heating of first- and second-order streams are minimal.

THERMAL RECOVERY

The increase in shade with revegetation becomes increasingly important as watersheds and steam channel networks accumulate a longer management history. The time required for "thermal recovery" after logging in riparian areas depends on factors such as stream width, stream azimuth, and local topography, as well as factors that affect riparian species composition and their rates of growth. Two studies conducted on the pacific coast indicated that increases in stream temperatures after logging lasted 3–7 years. No studies were found of temperature recovery in the Interior. However, other studies document increases in stream shade after logging. Shade recovery may take up to 20 years at higher elevations in the Oregon Cascades. Incorporating thermal recovery into the long-term management of stream temperature could be based on empirical relationships between stream shade and time since logging, grouped according to geographic variables.

CONCLUSION

A literature review on the effects of riparian management on stream temperature can be downloaded at www.for.gov.bc.ca/cariboo/research/hydro. The Ministry of Forests is identifying additional needs for stream temperature research and is developing management tools.

AUTHOR

* ***Correspondence to:*** Patrick Teti, B.C. Ministry of Forests, 200–640 Borland Street, Williams Lake, BC V2G 4T1.
E-mail: Pat.Teti@gems7.gov.bc.ca

Update on soil rehabilitation research in the southern Interior

CHARLES BULMER*, SHANNON BERCH, BILL CHAPMAN, MIKE CURRAN, DEREK HODGKINS, GRAEME HOPE, MELANIE JONES, MATTHEW PLOTNIKOFF, MARGARET SCHMIDT, KIRSTY VENNER, AND GUOPING XIAO

INTRODUCTION

Efforts to restore productivity to degraded soils have accelerated since the implementation of the Forest Practices Code, and because of investments made by Forest Renewal BC. Soil rehabilitation can be included as a strategy to maintain or enhance timber supply in the working forest. Restoring productivity to degraded soils can also enhance other environmental values.

Several research projects are under way in the southern Interior to keep pace with the demand for information on the effectiveness of common rehabilitation techniques, and to test approaches that may reduce the cost of such work. Here we summarize current results from a number of research projects that have been implemented recently in the southern Interior.

MATERIALS AND METHODS

We developed research summaries for seven research projects funded by Forest Renewal BC to provide recent results and interim recommendations. These projects pursued diverse approaches to research, including retrospective study, designed field and laboratory experiments, operational trials, and adaptive management monitoring. The characteristics of the approaches were compared and contrasted, especially the role each plays in developing an integrated research program to provide new and relevant information to rehabilitation practitioners. The results were then integrated into a statement of several principles to guide soil rehabilitation projects. Finally, contact information for each project was summarized so interested people can obtain more information.

RESULTS AND DISCUSSION

Retrospective Studies: Landings Rehabilitated by Winged Subsoiler

A research project was recently completed that evaluated the effectiveness of previous soil rehabilitation projects on landings in three Interior forest districts. Survival of planted lodgepole pine seedlings was

Citation —

Bulmer, C., S. Berch, B. Chapman, M. Curran, D. Hodgkins, G. Hope, M. Jones, M. Plotnikoff, M. Schmidt, K. Venner, and G. Xiao. 2000. Update on soil rehabilitation research in the southern Interior. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 29–32.

generally adequate to establish a new forest on these areas, although establishment problems occurred in one district. Growth rates on the rehabilitated landings ranged from 51% to roughly 100% of the growth in the adjacent plantations after 5 years. Surface soils on landings had lower C and N, but nutrient status and seedling growth were not correlated. Surface soils (to 20 cm) for both rehabilitated landings and regenerating plantations had bulk density values that were below the expected threshold for growth limitation. In contrast, the landings in one district, where penetration of a steel probe was restricted, also had slower tree growth.

Skid Road Rehabilitation Study, Nelson Forest Region

The Nelson Forest Region has a long history of rehabilitating constructed trails on steep slopes. This study observed that incomplete rehabilitation of skid roads, consisting of simple recontouring without full decompaction, commonly led to enhanced growth for trees planted on berms and sidecast soil material compared to trees growing on the former inner track and mid-road positions. Site-specific conditions, such as presence of calcareous soil material and choice of tree species, had an influence on the range of growth response observed at different parts of the skid roads. Skid-trail rehabilitation has evolved since the first work was carried out. Modern rehabilitation techniques, involving more complete water management, decompaction of the running surface, and retrieval of sidecast topsoil in layers, are expected to lead to improved success.

Experimental Research: Use of Wood Waste for Rehabilitation

Many waste materials that are unsuitable for further processing may be suitable for improving degraded soils. Experimental sites were established in 1998 to evaluate the use of woody residues for soil rehabilitation. At Okanagan Falls, an excavator decompacted landings and applied wood waste either as mulch or incorporated into the surface soil. Results showed that seedlings planted on the rehabilitated plots had better survival than those on the untreated control. A separate plot treated with wood waste and sewage sludge compost had poor seedling survival, and weed problems developed. The rehabilitation treatments reduced soil bulk density compared to the untreated control plots.

Experimental Research: Suitability of Biological Inoculants for Rehabilitation

Most roads and landings are comprised of subsoil with low biological activity and low inoculum potential for beneficial organisms such as mycorrhizae. Laboratory and field investigations have been undertaken to assess commercially available biological inoculants for their suitability to enhance seedling survival on rehabilitated roads and landings. Preliminary evaluations of seedlings produced in British Columbia showed tremendous variation in the amount of colonization between different nurseries and tree species. Douglas-fir had particularly low rates of mycorrhizal colonization. Two field sites were established in 1999 to evaluate field performance of inoculated and uninoculated seedlings. These field sites will be planted in spring, 2000.

Experimental Research: Air-vent Blocks and Microbial Inoculants

A research project is investigating whether or not root system development is altered in air-vent blocks compared to untreated or copper-treated styroblocks, and whether such alteration depends on the type of planting environment (e.g., rehabilitated landings). Interim results from first-year plantings near Princeton indicate that root egress in the upper part of the plug was stimulated by air-vent blocks, as well as by copper-treated styroblocks. In addition, first-year field growth was similar in both air-vent and copper blocks. A second site was established near Westwold in 1999 to further evaluate whether seedling and stock type differences can affect rehabilitation success.

Operational Trial: Landing Rehabilitation in the Cariboo

An extensive operational trial was established by Lignum Ltd. beginning in 1996 and continuing to 1999. The main study included 451 landings treated with various decompaction, soil amelioration, and revegetation techniques. A subsidiary cattle management trial, consisting of 131 landings, was established in 1998. Decompaction costs in 1997 varied from $204 per hectare for a disc trencher to $1725 per hectare for a silvatiller. For most treatments, average soil bulk density for decompacted soils was similar to that of adjacent plantations, indicating that machine cost and availability should be a major factor determining equipment choice for rehabilitation. Average seedling density after 1 year was 1329 stems per hectare for landings planted in 1997, and 1181 stems per hectare for landings planted in 1998. Seedling density was inversely related to grass cover on the landings. Cattle management strategies implemented in 1998 seemed to result in lower rates of basal scarring on seedlings.

Adaptive Management Monitoring: Adams Lake Landing Rehabilitation

Interfor (Adams Lake) began a program of landing rehabilitation in 1996, and continued until 1998. A monitoring project was recently implemented to evaluate the effectiveness of the work, and to establish permanent plots for further monitoring. Interim results indicate that seedling survival was somewhat lower than rates expected for plantations, but was generally above 1000 stems per hectare after 3 years, except in areas of high range use. Survival and growth were best for landings with medium- and coarse-textured soils.

SUMMARY

Recently implemented research on soil rehabilitation has adopted various approaches to developing and extending new knowledge. Retrospective studies have provided information quickly, but these studies are restricted to evaluation of existing projects. Experimental research addresses many of the subtle questions surrounding the long-term effects of numerous treatments. In addition to questions of effectiveness, costs and feasibility are evaluated through operational trials. Finally, where work is being carried out as part of existing programs, a monitoring plan can provide important information for enhancing the value of new work.

Early results from these projects suggest the following integrating principles can be adopted for forest soil rehabilitation in British Columbia.

- Survival rates for trees planted on rehabilitated landings may be lower than rates expected in plantations, but initial establishment of a new forest is still remarkably successful in many cases.
- A commercial tree crop may be possible from many rehabilitated areas. The best results are expected on medium- and coarse-textured soils.
- In areas of high range use, cattle damage is a significant challenge to restoration.
- Modern rehabilitation techniques, incorporating topsoil respreading, a wide range of equipment options, and a better understanding of seedling response factors have the potential to be more successful and less costly than work carried out in the past.

ADDITIONAL CONTACT INFORMATION

Retrospective studies of soil conditions and forest productivity on rehabilitated landings: Interior British Columbia. Matthew Plotnikoff and Margaret Schmidt, Simon Fraser University (Telephone: 604-291-3323).

Tree growth on rehabilitated skid roads in southwestern British Columbia. Mike Curran, Nelson Region, B.C. Ministry of Forests (Telephone: 250-354-6274).

Rehabilitation of forest roads and landings with wood waste. Kirsty Venner and Cindy Prescott, University of British Columbia (Telephone: 604-822-4701).

Suitability of biological inoculants for conifer seedlings on reclamation and standard reforestation sites. Guoping Xiao, University of British Columbia (Telephone: 250-604-328, Ext. 2618); Shannon Berch, Research Branch, B.C. Ministry of Forests (Telephone: 250-952-4122).

Air-vent blocks and microbial inoculants: effects on pine. Melanie Jones, Okanagan University College, Kelowna (Telephone: 250-862-5464, Ext. 755); Anne Flanagan, University of Alberta, Edmonton (Telephone: 780-492-3281); Steve Kiiskila or Peter Richter, Pacific Regeneration Technologies, Vernon, Prince George (Telephone: 250-963-9199).

Operational trials of landings rehabilitation: Lignum landing rehabilitation. Bill Chapman, Cariboo Region, B.C. Ministry of Forests, Williams Lake (Telephone: 250-398-4718); Derek Hodgkins and Ron Meister, Inland Timber Management, Williams Lake (Telephone: 250-392-7177).

Evaluation of seedling growth on rehabilitated landings: Adams Lake. Graeme Hope, Kamloops Region, B.C. Ministry of Forests, Kamloops (Telephone: 250-828-4176); Alan Thorne, Interfor, Adams Lake (Telephone: 250-679-3234).

AUTHOR

* ***Correspondence to:*** **Charles E. Bulmer**, Research Branch, B.C. Ministry of Forests, 3401 Reservoir Road, Vernon BC V1B 2C7.

E-mail: chuck.bulmer@gems8.gov.bc.ca

Barriers to integrating science into policy and practice

CHRIS HOLLSTEDT* AND KATHIE SWIFT†

INTRODUCTION

Developing community consensus on resource use is complex. People often develop a solution to a perceived problem in isolation from the parts of the community responsible for its implementation. Collective development and use of knowledge (let's call it "community wisdom") can often help groups work towards solutions.

Our initial perceptions of forest research investments in the southern Interior were that:

- the forest industry needed more research;
- research currently under way was not focused on operational needs; and
- current policies did not reflect the complete scientific picture.

To determine the accuracy of these perceptions, we conducted a series of analyses of client needs focusing on information needs, preferred information sources, barriers to using information, and barriers to using science in operations and policy development. Here we summarize our methodology and results.

METHODS

The methods used included focus workshops, comprehensive mail survey, one-on-one consultation, and small-group topical working sessions. The needs analyses focused on natural resource professionals, aboriginal natural resource leaders, policy developers, researchers, and educators in the southern Interior and in Victoria.

DISCUSSION

Table 1 outlines the important barriers that impede the link between science, policy, and practice.

REFERENCES

Dickie, A. 1999. Preliminary results from the Southern Interior aboriginal natural resources information needs analysis. Southern Interior Forest Extension and Research Partnership, Kamloops, B.C. Internal Report.

Citation —

Hollstedt, C. and K. Swift. 2000. Barriers to integrating science into policy and practice. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 33–4.

TABLE 1 *Summary of broad and specific barriers*[a]

Broad barriers	Specific barriers
Information Sources	• knowing "who's who" in the policy, research, and operational arenas • knowing what information is available • trusting the quality and source of the information • lack of local problem-solving initiatives • lack of synthesis
Information Access	• knowing where to find "who's who" • having the information in a form that is readily accessible • having the information in a form that is useful • having access to timely and interim information • access to extension professionals
Cultural Differences	• lack of flexible and open policy process • lack of an open regulatory framework • lack of time to learn • fundamental reality differences between and within the research, policy, and operational communities • centralized control of decisions • acceptance level of new innovations • organizational inertia • lack of respect and trust in experiential and indigenous knowledge
Technology	• limited access to emerging communication technologies • limited knowledge of how to use emerging communication technologies • lack of incentive to use new technology • fast pace of technological change and ability to adapt
Capacity	• time • money • skills • desire

a Adapted from Dickie (1999), Gregory and Satterfield (1999), and Hollstedt et al. (1999).

Gregory, R. and T. Satterfield. 1999. Southern Interior Forest Extension and Research Partnership client survey. B.C. Ministry of Forests and Southern Interior Forest Extension and Research Partnership, Victoria, B.C. Working Paper 40.

Hollstedt, C., S. Morford, and K. Swift. 1999. Sharing solutions and management models for community-based tenures in British Columbia. Workshop summary, August 11, 1999. Southern Interior Forest Extension and Research Partnership, Kamloops, B.C. File Rep. 99-6. http://www.siferp.org/infofr99-6.pdf

Personal Communication. SIFERP Extension Team Client Outreach.

AUTHORS

* ***Correspondence to:*** **Chris Hollstedt**, Southern Interior Forest Extension and Research Partnership, 478 St. Paul Street, Kamloops, BC V2C 2J6.

E-mail: chris.hollstedt@siferp.org

† Interior Lumber Manufacturers Association, Kelowna, B.C.

Timber supply and aesthetics at the landscape level: A fresh look at an old problem

STEPHEN SHEPPARD* AND PAUL PICARD†

INTRODUCTION

Alternative timber harvesting practices can potentially meet visual quality objectives in the more visible "front country," while relieving pressure on dwindling back country forest ecosystems. These methods may provide timber volumes that are substantially higher than is possible with clearcutting under typical visual resource management constraints.

MATERIALS AND METHOD

We reviewed selected case studies of the relationship between timber supply and aesthetics in North America, and summarized relevant aspects of the management of visual resources in British Columbia. We examined hypothetical relationships between timber supply and the intensity of visual resource management at the landscape level. These relationships were derived from available Ministry of Forest data (B.C. Ministry of Forests 1998B), which quantified what could be harvested under standard Visual Quality Objectives (VQOs) for both partial-cut and clearcut harvesting. A simple model was used to determine the available timber supply for any given combination of VQOs in a landscape unit (expressed as a "VQO intensity" index of 0–1, based on the proportion of land covered by more or less restrictive VQOs). As a preliminary example, these hypothetical relationships were examined in the context of the Arrow Forest District in the West Kootenays.

RESULTS AND DISCUSSION

Various studies suggest that, in forested landscapes, aesthetic public preferences decrease as the amount of visible landscape alteration increases (e.g., Berris and Bekker 1989). Accordingly, traditional visual resource management approaches using VQOs have assumed that increased visual sensitivity constrains timber supply (B.C. Ministry of Forests 1998B). Indeed, some researchers (e.g., Fight and Randall 1980) have found that VQOs lead to increased harvesting costs and lower timber availability. However, the true effects of visual resource management on timber supply will depend on:

- the extent of overlapping constraints from other non-timber resource values and policies;
- the method of determining acceptable harvesting levels to meet a given VQO; and
- the forest practices used.

CITATION —

Sheppard, S.R.J. and P. Picard. 2000. Timber supply and aesthetics at the landscape level: a fresh look at an old problem. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 35–8.

Various partial-cutting practices have proven successful in meeting VQOs in visually sensitive areas (Fight and Randall 1980), and have even increased both timber supply and aesthetic quality (McDonald and Litton 1998).

Established VQOs, as currently implemented under Forest Practices Code and Timber Supply Review procedures, essentially constitute a kind of zoning in which less timber harvesting is allowed in areas with more sensitive views. Recently, this system has been changed whereby, unless otherwise stated in a Higher-level Plan, the District Manager is provided with full discretion in managing (or not managing) visual resources (B.C. Ministry of Forests 1998B); this includes the authority to relax existing VQOs where they conflict with timber needs. Figure 1 summarizes how visual resources are managed in British Columbia.

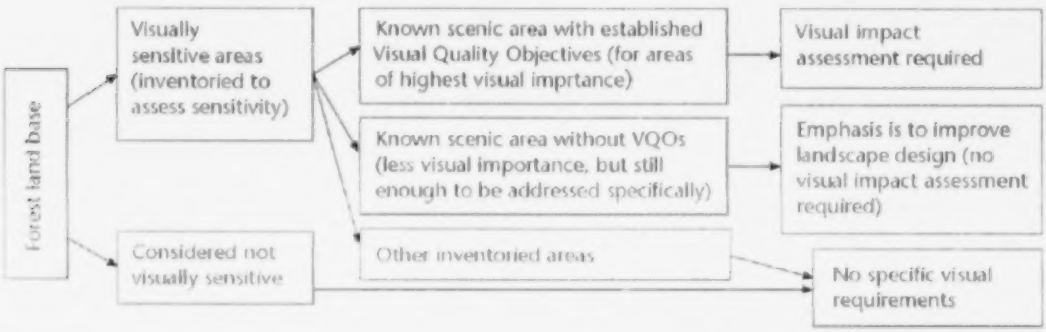
Forest land base
Visually sensitive areas (inventoried to assess sensitivity)
Considered not visually sensitive
Known scenic area with established Visual Quality Objectives (for areas of highest visual imprtance)
Known scenic area without VQOs (less visual importance, but still enough to be addressed specifically)
Other inventoried areas
Visual impact assessment required
Emphasis is to improve landscape design (no visual impact assessment required)
No specific visual requirements

FIGURE 1 *Visual resources management scenarios in British Columbia (adapted from B.C. Ministry of Forests 1998A).*

The prescriptive approach to VQOs, as an automatic constraint on timber supply, can ignore substantial opportunities to meet objectives with increased timber harvesting through partial cutting and better design. While Ministry of Forests guidance recognizes the benefits of landscape design in a more flexible approach to harvest planning, in areas with established VQOs the typical process may lead either to timber being "locked up" unnecessarily in the "front country" at the expense of the backcountry or mill closures, or to a wholesale relaxation of visual controls which may lead to a public backlash.

These problems and potential solutions can be illuminated through an examination of recent Ministry studies and policy guidance. Public perception studies (B.C. Ministry of Forests 1997) were conducted in which the public ranked different levels of landscape alteration or denudation from timber harvesting (clearcuts and partial cuts) on their visual quality. These results were used in Timber Supply Reviews to factor in the effects of visual resource management. This was done by establishing norms for basal area (for partial cuts) and "percent denudation" (for clearcuts) allowed for harvest while meeting given VQOs (see B.C. Ministry of Forests 1998B).

The relationships derived from these norms (Figure 2) indicate that where VQOs have been established, timber supply could potentially be significantly increased using certain kinds of partial cutting. In all cases, partial cutting appears to offer either equivalent or increased timber supplies for any given combination of VQOs in a landscape unit. Results also indicate that much higher visual quality could be achieved through partial cutting for a given level of timber supply. In essence, the perception studies found that people detect and react adversely to much smaller harvested volumes if these are clearcut rather than partially cut, although further testing at the higher volume partial cuts is warranted.

How would these hypothetical relationships affect, for example, the case of the Arrow Forest District, where much of the remaining merchantable timber (18.8% of the land base available for harvest) occurs

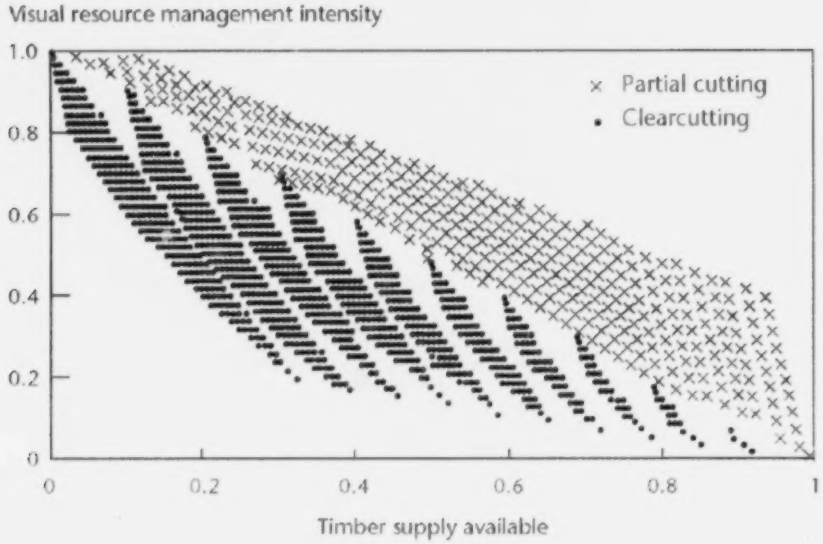

FIGURE 2 *Theoretical relationships (index values) between the management of visual resources and available timber supply under both clearcutting and partial cutting.*

in the front country under restrictive VQOs (B.C. Ministry of Forests 1994)? Within these areas, the effects of VQOs on timber supply could theoretically be reduced by as much as 10.3% (from a 17% constraint on timber supply down to 6.25%) by using partial cutting, without sacrificing visual quality. However, these figures must be viewed with great caution because:

- other forest cover constraints may reduce this effect (e.g., community watershed constraints, which also contribute to meeting VQOs); and
- procedural, operational, and financial issues may limit the feasibility of partial cutting.

In conclusion, the application of the "percent alteration/denudation" measure used under a clearcut system may be unnecessarily restrictive in some cases; VQOs should be used as an effective performance standard, not a blanket timber supply constraint. Alternative forest practices, such as partial cutting systems (where feasible) and innovative landscape design, may represent a "win–win" situation for visual quality and timber supply, with potential benefits to community acceptance and backcountry ecosystems. However, forest health and windthrow risks, increased costs, lack of training, and longer layout/approval processes may limit feasibility. Thorough studies of these more complex relationships must be conducted.

REFERENCES

Berris, Catherine and Pieter Bekker. 1989. Logging in Kootenay landscapes: the public response. B.C. Ministry of Forests, Victoria, B.C. Land Management Report No. 57.

B.C. Ministry of Forests. 1994. Arrow Timber Supply Analysis Report. Timber Supply Branch, Victoria, B.C.

_____. 1997. Visual impacts of partial cutting: summary report. Technical analysis and public perception study. Forest Development Section, Forest Practices Branch, Victoria, B.C.

_____. 1998A. Framework for managing visual resources to mitigate impacts on timber supply. Forest Development Section, Forest Practices Branch, Victoria, B.C.

_____. 1998B. Procedures for factoring visual resources into timber supply analyses. Forest Development Section, Forest Practices Branch, Victoria, B.C.

Fight, D. Roger and M. Robert Randall. 1980. Visual quality and the cost of growing timber. Journal of Forestry 78(9):546–8.

McDonald, P.M. and R.B. Litton. 1998. Combining silviculture and landscape architecture to enhance roadside view. U.S. Department of Agriculture, Forest Service, Berkeley, Calif. Research Paper No. 235.

AUTHORS

* ***Correspondence to:*** **Stephen R.J. Sheppard,** Forest Resources Management and Landscape Architecture, Forest Sciences Centre, 2424 Main Mall, University of British Columbia, Vancouver, BC V6T 1Z4.

E-mail: shep@interchg.ubc.ca

[1] Forest Resource Management, Forest Sciences Centre, University of British Columbia.

Old-growth structural attributes in managed forests: Is there a vision?

THOMAS SULLIVAN*, DRUSCILLA SULLIVAN†, AND PONTUS LINDGREN‡

INTRODUCTION

Management of forested landscapes for biological diversity is a major objective across North America. Perhaps the greatest potential to diversify future forests lies in the vast areas of young second-growth stands, which may be managed silviculturally to accelerate ecosystem development. We designed this study to test several hypotheses related to large-scale pre-commercial thinning over a range of stand densities at ages 17–27 years. We hypothesized that such management over the 10-year period since treatment would enhance:

- productivity and old-growth structural features (crown volume, diameter, and height growth) of lodgepole pine (*Pinus contorta*) crop trees;
- stand structure attributes (species diversity and structural diversity of herb, shrub, and tree layers); and
- species richness and diversity of small mammal communities on the forest floor.

MATERIALS AND METHODS

Study areas were located near Penticton, Kamloops, and Prince George in south-central British Columbia. Each study area had three stands thinned in 1988 to densities of about 500 (low), 1000 (medium), and 2000 (high) stems per hectare, with an unthinned juvenile pine and old-growth pine stand for comparison. Understorey vegetation was measured in all stands in 1990, 1993, and 1998. Stand structure (coniferous tree layers) was measured in 1998. Small mammal populations were sampled intensively in 1990, 1991, and 1998.

RESULTS AND DISCUSSION

Mean diameter increments of trees in the low-density stands were significantly higher than those in the medium- and high-density stands at all study areas. Mean height increments of trees were similar among stands. Trees in both the low- (42.3 m^3) and medium-density (42.9 m^3) stands had greater crown volumes than those in the high-density (27.3 m^3) and unthinned (12.5 m^3) stands. No difference in the volume of coarse woody debris on the forest floor was evident among stands.

CITATION —

Sullivan, T.P., D.S. Sullivan, and P.M.F. Lindgren. 2000. Old-growth structural attributes in managed forests: is there a vision? *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 39–40.

Crown volume index (biomass) of herbs was highest in the thinned stands by 1998, but no difference existed among stands for shrubs and trees; mosses were highest in the old-growth stands. Mean species richness and diversity of herbs, shrubs, and trees were similar among stands at 2, 5, and 10 years after thinning. However, mean species diversity and structural diversity of coniferous trees were significantly higher in the low- and medium-density stands than in the high-density and unthinned stands 10 years after thinning. Total structural diversity of all vegetation in the low-density stands was significantly greater than that of the medium-density, unthinned, and old-growth stands in 1998.

Mean abundance of red-backed voles (*Clethrionomys gapperi*) was consistently higher (2.1–3.3 times) in the old-growth than unthinned stands, and this value was higher than those in the thinned stands in 1998. Mean numbers of deer mice (*Peromyscus maniculatus*) were highest in the unthinned and high-density stands in 1990–1991, with no differences among stands in 1998. Northwestern chipmunks (*Tamias amoenus*) were at similar numbers among stands in 1990–1991 and at higher numbers in the low- and medium-density stands in 1998. Voles (*Microtus* spp., *Phenacomys intermedius*) and shrews (*Sorex* spp.) had similar mean numbers among treatment stands. Mean abundance of short-tailed weasels (*Mustela erminea*) was higher in the low-density stands than high-density, unthinned, or old-growth stands in 1990–1991, with no difference among stands in 1998. Mean species richness and species diversity of small mammals were highest in the low-density and medium-density stands.

Heavily thinned lodgepole pine stands appear to develop some old-growth structural attributes, such as large diameter trees, crowns, and structurally diverse vegetation understoreys. Small mammal communities on the forest floor appear to reflect the compositional and structural diversity of these managed stands. Replicate study areas covering three forest ecological zones have achieved these results. A snag creation program is required in these stands to provide habitat for cavity-using species. Responses of other species groups to these "old-growth" attributes should be monitored.

AUTHORS

* ***Correspondence to:*** **Thomas P. Sullivan**, Applied Mammal Research Institute, 11010 Mitchell Avenue, R.R. #3, Site 46, Comp. 18, Summerland, B.C. V0H 1Z0.

E-mail: sullivan@bc.sympatico.ca

† Applied Mammal Research Institute

‡ Applied Mammal Research Institute

Refining definitions of old growth to aid in locating old-growth forest reserves

TOM BRAUMANDL* AND RACHEL HOLT†

INTRODUCTION

Retaining certain levels of old forest is a cornerstone of the provincial government's biodiversity management strategy. The work we describe involves implementing old-growth retention on the ground with guidance from science. We propose a methodology that consists of two parts:

- a coarse-scale methodology for identification of old forest based on appropriate stand structural attributes (using an aerial inventory); and
- a fine-scale scorecard approach to ranking controversial patches based on an index of "old-growthness," assessed on the ground.

Here we deal primarily with the derivation of the fine-scale index (details of this project are presented in Holt et al. 1999).

The task of laying out old-growth reserves starts with answering the basic question: What is old growth? Definitions of old-growth forest range from those based solely on forest age estimates (B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995) to those derived from principles of forest stand development (Oliver and Larson 1990). Several authors endorse the use of definitions grounded on multiple structural attributes because these structures represent some of the functional aspects of old-growth forests (Spies and Franklin 1988; Franklin and Spies 1991; Marcot et al. 1991; Kneeshaw and Burton 1998; Wells et al. 1998). Attributes used in some ecological old-growth definitions include: large old trees, a multilayered canopy, numerous large snags and logs, diverse tree community, great age of some trees, canopy gaps, hummocky microtopography, complex structure, wider tree spacing, and increased understorey production (from Kneeshaw and Burton 1998; see also Franklin and Spies 1991; Holt and Steeger 1998).

The definition of old growth currently employed by forest planners in British Columbia is based on stand age taken from forest cover maps. This allows the use of provincial forest inventory information without having to incur ground-sampling costs. However, this simple working definition does not evaluate stand structural attributes. Defining old growth without assessment of structure may consequently fail to identify the most biologically important areas of forest.

To supplement the definition of old-growth forest derived solely from mapped stand age, we first suggest a coarse check of potential reserve value. Candidate reserves are viewed from the air. The presence of stand attributes (e.g., appropriate trees, snags, veteran trees, etc.) and landscape-level features (e.g., size, shape, position, landscape context, etc.) are noted for each patch. This approach allows for the checking of map typing. The potential biodiversity value of each patch can then be ranked superficially

Citation —

Braumandl, T.F. and R.F. Holt. 2000. Refining definitions of old growth to aid in locating old-growth forest reserves. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 41–4.

in relation to other patches available in the area. However, in some cases (e.g., where disputes exist, or where biodiversity values are not clearly determined from the air) ground checking will be necessary.

Ecological definitions of old growth can take the form of minimum criteria, or indices. Although minimum criteria may be easier to develop, many authors support the use of continuous indices. These are thought to better account for the inherent variability of old-growth stands, and can provide a relative ranking of stands (Wells et al. 1998). Thus, stands are not dismissed because they "fail to meet old-growth standards," but are instead given a relative ranking based on the abundance of a number of attributes.

METHODS

Thirty-six stands were chosen in the Arrow and Kootenay Lake forest districts within the Interior Cedar–Hemlock (ICH) biogeoclimatic zone. Eighteen stands were selected in each of ICHdw and the ICHmw2 variants. Stands, with a minimum size of 10 ha, represented a range of stand ages from 100 to greater than 250 years. Three circular 0.1-ha (17.8 m radius) plots were sampled per stand. The following variables were assessed:

- number of trees > 50 cm DBH
- largest tree diameter
- number of snags in 12.5–25, 25–50, > 50 cm DBH classes
- largest diameter snag
- % of trees > 50 cm DBH with pathological indicator
- multiple canopy layer presence
- number of tree species
- cover and modal height of shrubs and herbs
- % of trees > 50 cm DBH with dead or broken top
- mean and modal LFH thickness
- density of trees in the DBH classes < 12.5 cm; 12.5–40 cm; 40–50 cm, and < 1.3 m tall
- relative abundance and size of canopy gaps
- arboreal lichen abundance

The number of pieces of downed logs greater than 30 cm in diameter were tallied along line-intersect transects. Age was measured on dominant or codominant trees and the largest trees in the stand.

Principal component analysis (PCA) was used to ordinate data collected from plots within stands. Our objective was to find a set of structural attributes that best described the main relationships between plots. Analyses were conducted separately for each BEC (biogeoclimatic ecosystem classification) variant. Only results for the ICHmw2 variant are discussed here.

RESULTS AND DISCUSSION

Two major plot groups were obvious from looking at the ordination (an "old" and a "not-old" group). While not as clearly apparent as the first two groups, the ordination helped identify plots within the "not old" group that contained the most "old" attributes—that is, the recruitment class. The recruitment class was important to define because many landscape units do not contain sufficient old forest to meet policy targets, and hence old-growth reserves must be "recruited" from younger forest in the shortest time possible.

To provide an index for "old-growthness" from our limited pilot study data, we decided to use an approach that does not attempt to weight attributes. Our approach was to use the groups of plots generated by the PCA for each BEC variant to produce a table of threshold values for each attribute that clearly distinguished our structural classes (see Table 1).

To implement this procedure, a surveyor establishes three plots per stand and scores the stand according to the threshold values. This procedure takes about 3 hours. Given present budget constraints,

TABLE 1 *Threshold values for attributes in the ICHmw2, per hectare*

Attribute/Score	⇐ Not old 1	Threshold	Recruitment 2	Threshold	Old ⇒ 3
Mean age		147		286	
Mean maximum age		204		411	
Density trees > 50 cm DBH		25		84	
Largest DBH		57		74	
Percent big trees with broken/deadtops		13		28	
Percent big trees with pathogens		18		36	
Snags > 50 cm DBH		11		18	
Snags 10–25cm DBH		78		44	

this procedure would most likely be used for contentious stands (e.g., a licensee proposes an alternative candidate reserve to those proposed by government). Both coarse- and fine-scale processes should provide an objective ranking of stand quality in an operationally feasible way. By providing a functionally based definition of old growth, a more effective conservation network could be designated. In addition, management's mandate to maintain a certain amount of old forest would be delivered in a scientifically defensible manner.

In our introduction, we intimated that defining old growth is only the first step in designing an old-growth reserve network. There are numerous landscape (e.g., location, size of individual reserves, historic levels of old growth, biodiversity issues within the working forest) and social issues (timber impact) that also must be taken into account. We (managers and scientists) continue on our quest for the perfect conservation network.

REFERENCES

B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks. 1995. Biodiversity guidebook. Forest Practices Code, Victoria, B.C.

Franklin, J.F. and T.A. Spies. 1991. Ecological definitions of old-growth Douglas-fir forests. *In* Wildlife and vegetation of unmanaged Douglas-fir forests. L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff (technical coordinators). U.S. Department of Agriculture, Forest Service, Portland, Oreg. General Technical Report PNW-285.

Holt, R.F and C. Steeger 1998. An ecological methodology for old seral identification, assessment and ranking at a landscape scale, in the Nelson Forest Region: Phase II. Kootenay Boundary Land Use Implementation Task Force, Nelson Forest Region, Nelson, B.C. Final report.

Holt, R.F., T.F. Braumandl, and D. Mackillop. 1999. An index of old-growthness for two BEC variants in the Nelson Forest Region. Inter-agency Management Committee Land Use Coordination Office, B.C. Ministry of Environment, Lands and Parks, Nelson, B.C. Unpublished Report.

Kneeshaw, D.D. and P.J. Burton. 1998. Assessment of functional old-growth status: a case study in the Sub-boreal Spruce Zone of British Columbia, Canada. Natural Areas Journal 18:293–308.

Marcot, B.G., R.S. Holthausen, J. Teply, and W.D. Carrier. 1991. Old-growth inventories: status, definitions, and visions for the future. *In* Wildlife and vegetation of unmanaged Douglas-fir forests. L.F. Ruggiero, K.B. Aubry, A.B. Carey, and M.H. Huff (technical coordinators). U.S. Department of Agriculture, Forest Service, Portland, Oreg. General Technical Report PNW-285.

Oliver, C.D. and B.C. Larson. 1990. Forest stand dynamics. McGraw-Hill, New York, N.Y.

Spies, T.A. and J.F. Franklin. 1988. Old-growth and forest dynamics in the Douglas-fir region of western Oregon and Washington. Natural Areas Journal 8:190–201.

Wells, R., K.P. Lertzman, and S.C. Saunders. 1998. Old-growth definitions for the forests of British Columbia, Canada. Natural Areas Journal 18:279–92.

AUTHORS

* ***Correspondence to:*** **Tom F. Braumandl**, B.C. Forest Service, 518 Lake St., Nelson, BC V1L 4C6.
E-mail: tom.braumandl@gems5.gov.bc.ca

† Pandion Ecological Research Ltd., Nelson, B.C.

EcoGen: A model for predictive ecosystem mapping

DEL MEIDINGER*, BRUCE ENNS†, ALLEN BANNER‡, AND COLLEEN JONES§

INTRODUCTION

Over the past few years, predictive ecosystem mapping (PEM) approaches to resource inventory have presented an alternative to more conventional mapping and classification methods such as terrestrial ecosystem mapping (TEM). This PEM information, as with TEM, is purported to support a wide range of resource planning needs ranging from strategic-level planning to more detailed on-site applications. Although PEM is new to British Columbia, PEM models have been evolving over the past decade. The EcoGen model is a PEM method being developed by the B.C. Ministry of Forests. It will provide TEM-like information for more geographically extensive areas, more readily and more cost-effectively, and will be used for site quality and ecologically based yield analyses.

Conventional resource inventories, as we have known them for decades, are undergoing radical technical and business model changes. This technical evolution is being driven by new digital capabilities in acquiring, processing, integrating, and sharing resource information and knowledge. It involves various technologies, such as remote sensing, image processing, GIS, and knowledge-based systems and information networks. Concurrent with this technical evolution is a trend towards greater data and information integration across inventory programs. With the present fiscal environment, people are now looking at opportunities for gaining efficiencies and greater information integration. The development of predictive ecosystem mapping is a result of these changes.

PREDICTIVE ECOSYSTEM MAPPING

Ecological classification systems provide a framework to organize and communicate our knowledge about the nature of physical and biotic features of landscapes. In British Columbia, the biogeoclimatic ecosystem classification (BEC) system has provided a classification of the basic ecological units in the province and is an integral component of forest management. The PEM and TEM approaches map the ecosystem units of the BEC at a large scale.

Predictive ecosystem mapping is a new and evolving inventory approach designed to use available spatial data and knowledge of ecological and landscape relationships to automate the computer generation of ecosystem maps. It typically involves the spatial overlay of mapped themes and the processing of the resultant attributes against a formalized knowledge base using automated inference methods. It offers the promise of providing surrogate terrestrial ecosystem maps. Figure 1 illustrates the overall principle of PEM—that ecological map delineation can be derived from other digital maps and the attributes associated with their polygons.

Citation —

Meidinger, D., B. Enns, A. Banner, and C. Jones. 2000. EcoGen: a model for predictive ecosystem mapping. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 45–7.

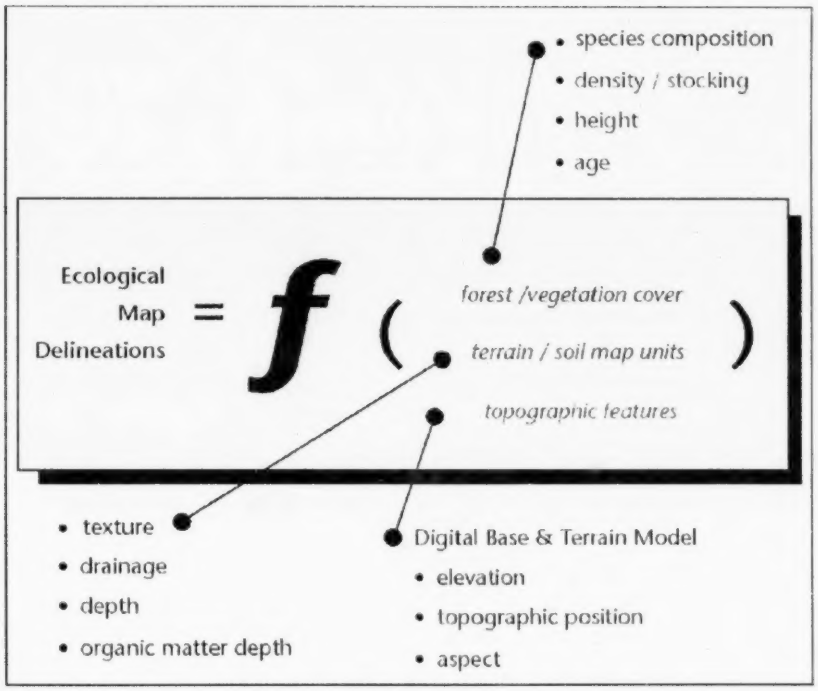

FIGURE 1 *General model of predictive ecosystem mapping.*

The advantages of PEM are many. The development of PEM has been driven by the need to address the high cost of conventional ecosystem mapping approaches. While savings in costs and time are possible over traditional approaches, other advantages deserve equal emphasis.

- Improvements in inventory cost, production, and human resource capacity: PEM approaches provide a more systematic, consistent, and repeatable stratification process; are reasonably flexible; adjust to changing information and knowledge sources; and offer opportunities to increase the rate and efficiency of mapping.
- Capitalize on, add value to, and protect investments in classifications and resource inventories: as many inventories are already available digitally, and we have an existing ecological classification system, PEM will provide more explicit and documented capture of the relationship knowledge. This will provide greater understanding of ecosystem and landscape relationships and how to best map these features in subsequent iterations.

Predictive ecosystem mapping also presents some disadvantages.

- Existing map information bases lack quality: existing map input sources for PEM may be absent, non-digital, of an inappropriate scale or survey intensity level, or may simply be of poor positional or thematic quality.
- Existing ecological knowledge lacks adequate quality: ecological classifications may be absent or of limited value for the area under consideration.
- Relationships between ecosystem classes and attributes in existing digital data are poor: poor linkages may result in unacceptable or ambiguous predictions.

THE ECOGEN MODEL

Figure 2 provides an overview of the EcoGen model. EcoGen uses available geographic and inventory data to map site series. Ecosystem maps produced by EcoGen can be used for wildlife interpretations in land management planning, for analyses of potential timber yields using site index–biogeoclimatic ecosystem classification (SIBEC) relationships, or for any other ecosystem-based interpretive needs.

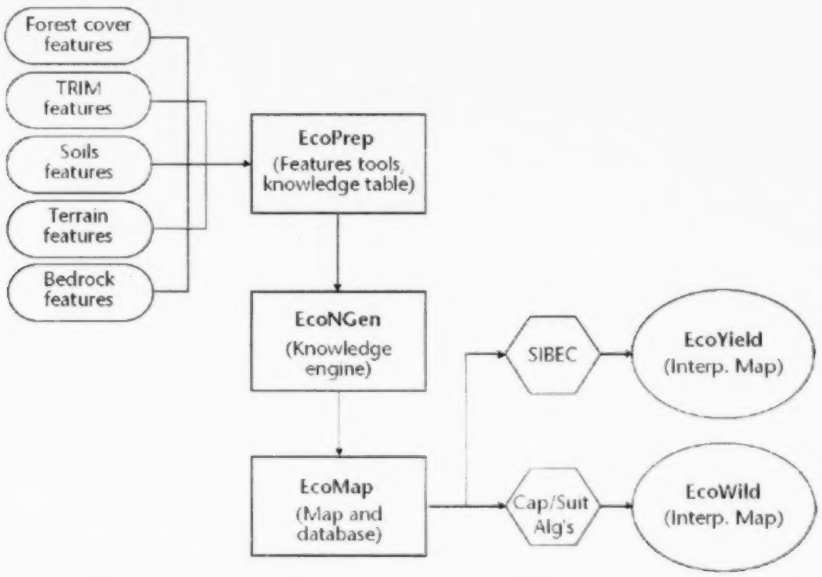

FIGURE 2 *Components to EcoGen Model (see also: http://www.for.gov.bc.ca/research/EcoGen)*

At present, EcoGen is not fully functional. The EcoNGen module is available and is being used to process data and knowledge tables for several large projects. The "features tools" within EcoPrep are nearly completed and are being evaluated in a pilot project in the Telkwa area. The EcoMap module will compile the attribute data in a TEM-like database format, as soon as the custodian for PEM has determined the final format. The interpretive algorithms for the EcoYield or EcoWild modules are concepts at this point and have not been programmed into the model.

The EcoGen model engine, EcoNGen, is in use for projects in the Merritt District (IFPA), Arrow District (IFPA), and Wood River. There is also interest in applying it in the Clearwater District, as a pilot project. We project that a "beta" release of the model will be available for testing in March 2000.

AUTHORS

• ***Correspondence to:*** **Del Meidinger**, B.C. Ministry of Forests, Research Branch, PO Box 9519, Stn Prov Govt, Victoria, BC V8W 9C2.

E-mail: Del.Meidinger@gems2.gov.bc.ca

† B.C. Ministry of Forests, Research Branch
‡ B.C. Ministry of Forests, Prince Rupert Forest Region, Forest Sciences Section
§ Shamaya Consulting, Smithers, B.C.

We're harvesting timber and maintaining caribou habitat: What about silviculture and other concerns?

TERESA NEWSOME*, MICHAELA WATERHOUSE†, HAROLD ARMLEDER‡, AND ORDELL STEEN§

INTRODUCTION

The importance of maintaining mountain caribou habitat in the Quesnel Highland portion of the Cariboo Forest Region was widely recognized by the early 1980s. At that time, a 20-year timber harvesting deferral was established over much of this area. When the Cariboo-Chilcotin Land Use Plan (CCLUP) Implementation Process Final Report (Province of British Columbia 1995) was released, the area under the timber harvesting deferral for caribou habitat was designated as 35% modified harvest and 65% no harvest. The CCLUP allows operational timber harvesting within the modified harvest zone to begin as early as year 2000.

Winter habitat for mountain caribou in the Cariboo Forest Region is found primarily at elevations above 1400 m in mature and old Engelmann Spruce–Subalpine (ESSF) forests that have abundant arboreal lichens. Arboreal lichen is the major food source for caribou during winter months. Most of the winter range habitat in the Cariboo Forest Region falls within the ESSFwc biogeoclimatic subzone variant, with a smaller portion at high elevation in the ESSFwk variant. Caribou prefer slopes that are less than 45%, but occasionally use steeper terrain. They require large tracks of land with adequate food resources so that populations can widely disperse over the landscape and thereby limit predation. Clearcutting has been the most common silvicultural system used in these ecosystems. However, it removes the entire arboreal lichen source and more than 100 years will be required for a clearcut patch to provide adequate lichen forage for caribou. Consequently, a harvested area managed under normal rotations may never provide suitable caribou habitat. Therefore, a group-selection silvicultural system has been recommended by the Cariboo-Chilcotin Land Use Plan Caribou Strategy as a means to continuously retain suitable lichen-producing habitat throughout the winter range area.

Research was initiated as early as 1989 in the Cariboo Forest Region to study silvicultural systems that would maintain mountain caribou habitat. Based on initial studies, researchers recommended a group-selection silvicultural system in which 33% of the timber is removed every 80 years. Recommended opening sizes can vary, but should not exceed 1.0 ha. Although initial indications are that this silvicultural system would likely provide suitable habitat for caribou, concerns were expressed about other aspects of forest management. Can the regeneration on these sites meet all the silviculture obligations as outlined in the Forest Practices Code? Will windthrow be a problem? Is this method of harvesting operationally feasible? Although answers to these questions are still under investigation, results from 7 years of research are providing some guidance.

CITATION —

Newsome, T.A., M.J. Waterhouse, H.M. Armleder, O.A. Steen. 2000. We're harvesting timber and maintaining caribou habitat: what about silviculture and other concerns? *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 49–53.

Research began with a pilot trial in 1990. A group-selection system with two opening sizes (0.03 and 0.008 ha) and an uncut control was established. Concerns regarding harvesting feasibility and seedling growth on the smallest opening size led to a change in the next stage of the research when a larger replicated trial (EP 1104.02) was logged in the winter of 1992/93. In this trial, three opening sizes (1.0, 0.13, and 0.03 ha) and an uncut control were tested on three sites. One site was located at Blackbear Creek with an elevation range of 1370–1550 m. The other two sites were located in the Grain Creek drainage. The Upper Grain Creek site had an elevation range of 1460–1680 m; the Lower Grain Creek site had a range of 1525–1740 m. A third stage of this research includes an adaptive management trial in which approximately 1000 ha will be partially cut over a period of 3–4 years using a group-selection system. An adjacent area, which is over 2000 ha, will be left as an untreated control. This stage will provide information on the use of large, partially logged areas by caribou and will allow a better assessment of operational concerns. The first block is scheduled for logging in March and April 2000. Because of concerns regarding seedling growth and financial feasibility, the smallest opening size (0.03 ha) was dropped. Openings on the adaptive management trial range in size from 0.1–1.0 ha, with various sizes in between.

METHODS

Research efforts have concentrated on the replicated trial (EP 1104.02), where numerous studies have been completed. Here, we discuss the regeneration, microclimate, and windthrow results. This trial also includes studies of stand structure, lichen abundance and distribution, lichen growth, breeding bird communities, small mammal communities, and snow distribution and melt.

Most studies were replicated over all three sites but, because of costs, microclimate was extensively studied only at the Blackbear Creek site. One climate station was established at each of the Grain Creek sites in a 1-ha opening. At Blackbear Creek, microclimate was monitored in one opening of each size. A climate station was established in the centre and a grid of temperature probes recorded air, soil surface, and soil temperature at designated intervals across the opening. Microclimate was also recorded in the uncut control and an adjacent clearcut, and was monitored for 6 years in all locations. Windthrow has been monitored regularly along systematically established transects.

Natural regeneration is being assessed in the openings to determine whether it is a viable regeneration option. Natural regeneration ingress densities are being monitored on 1164 plots of 1 ha^2, equally distributed among the three opening sizes (0.03, 0.13, and 1.0 ha) and randomly located within selected openings in each opening size. On one-half of the plots, scarification removed all vegetation and soil organic layers to create a mineral soil seedbed. The remaining one-half of the plots were not scarified. One-half of the scarified plots and one-half of the non-scarified plots were artificially seeded with spruce and subalpine fir seed to determine whether the amount of seed limits natural regeneration success. Seed traps were placed on selected openings to assess the abundance of natural seed rain.

Artificial regeneration is also being tested. Three species (subalpine fir, Engelmann spruce, and lodgepole pine), which were present before harvesting, were planted on five different planting treatments within all opening sizes. The five planting treatments included: three microsite locations, a large mineral screef (50 × 50 cm) created by a hand-held Hawke scarifier, and a control, where the seedlings were planted in a grid with no emphasis on microsite. Microsite planting treatments included:

- raised sites, which promoted better drainage and increased soil warming;
- protected sites, which were behind obstacles to avoid mechanical damage from snow creep; and
- planting spots, which were composed of rotten wood.

RESULTS AND DISCUSSION

Microclimate

These ESSFwc3 sites are cold and wet. Principal factors limiting seedling growth are short growing seasons, cool growing season temperatures, and in some situations, excess moisture. Growing season frosts are uncommon on the steep slopes. The group-selection method limits soil warming compared to a clearcut because the adjacent forest canopy shades a high proportion of the logged area. This shading can have two detrimental effects: it can reduce the growing season by delaying the snow melt, and it can cause lower air and soil temperatures during the growing season on northern and eastern aspects of the openings (Table 1). The accumulated degree-days in the large opening (1.0 ha) are lower than those in a clearcut located below the Blackbear Creek installation. The degree-days in the large openings at Upper Grain Creek and Lower Grain Creek were lower that those recorded at the Blackbear site (555, 605, and 639, respectively) in 1998 indicating a lower growth potential.

TABLE 1 *Effects of opening size and location (distance from centre) within an opening on accumulated 5°C growing degree-days between May 1 and September 30, 1994 in the 0.03, 0.13, and 1.0 ha partial-cut treatments at Blackbear Creek*

	0.03 ha			0.13 ha			1.0 ha			
Aspect	0 m Centre	7 m	10 m Edge	0 m Centre	14 m	20 m Edge	0 m Centre	32 m	40 m	56 m Edge
S	478	410	423	523	515	435	570	572	560	548
W	478	377	373	523	507	419	570	553	439	390
N	478	371	370	523	505	440	570	458	514	389
E	478	421	451	523	502	420	570	518	342	334

Natural Regeneration

Cone and seed production in these high-elevation forests is highly variable, both in time and in space. At the Blackbear Creek site, the number of seeds collected in traps was high in 1993 (167 filled seed per m^2), but much lower (< 10 per m^2) during each of the following 3 years. At the two Grain Creek sites, the 1993 peak in seed numbers was very reduced (4 seeds per m^2), and numbers of seeds in other years were less than 1 seed per m^2 Mean numbers of subalpine fir seed followed similar trends, but were generally smaller than mean numbers of spruce.

Five years after logging at the Blackbear Creek, site mean densities of spruce and subalpine fir seedlings were higher on scarified sites (3.3 and 10.1 seedlings per m^2) than on non-scarified sites (0.3 and 2.0 seedlings per m^2). Artificially applied seed had no significant effect on seedling densities, indicating that seed supply on this site was not limiting. Seedling densities were generally highest in the first year of measurement—the year following the peak seed rain—and declined steadily throughout the period of measurement. Subalpine fir seedling densities were smaller on large openings rather than on either medium or small openings, but spruce seedling densities showed no relationship to harvested opening size.

Natural regeneration densities were much smaller at the two Grain Creek sites than at the Blackbear Creek site. This was probably due to the much smaller natural seed rain at these sites. Five years after logging, spruce seedling densities averaged only 0.2 seedlings per m^2 on scarified and 0.3 seedlings

per m^2 on non-scarified sites. In contrast to the Blackbear Creek site, seedling densities were consistently higher on artificially seeded sites than on unseeded sites.

Seven years after logging, heights of spruce and subalpine fir natural regeneration were not sufficient to meet current height requirements contained in stocking standards for the area.

These results indicate that natural regeneration ingress may successfully regenerate openings of 1 ha or less, provided that a year of high seed production occurs shortly after logging. In addition, height requirements in stocking standards for the area would need to be adjusted. However, the unreliability of cone and seed production at these high elevations makes it very difficult to predict natural regeneration success after any given year of logging.

Artificial Regeneration

Five-year results indicate that planted seedling growth and survival generally decrease with increasing elevation and decreasing opening size (Tables 2 and 3). One exception is spruce on the Blackbear Creek site, where differences in growth were minimal between the medium and large openings.

Differences in seedling performance on the microsite treatments were minimal. Survival was lowest for all species on the control, where there was no site preparation or microsite consideration.

Will free-growing and stocking standards be met? Survival is a concern on some treatment combinations as is evident in Table 1. At the current growth rates, minimum heights contained in current free-growing and stocking standards may be difficult to achieve for pine (1.6 m) in the small openings on all sites, and the medium openings at Lower Grain Creek. Minimum height requirements may be difficult to achieve with subalpine fir (0.8 m) on the small and medium openings at Lower Grain Creek. Spruce would make the current minimum height (0.8 m) standards for free growing on all sites and opening sizes. These figures may underestimate the ability to meet height standards since height growth is expected to accelerate over the next few years.

TABLE 2 *Five-year percent seedling survival (values less than 50% are bolded)*

	Subalpine fir			Lodgepole pine			Engelmann spruce		
Site	1.0 ha	0.13 ha	0.03 ha	1.0 ha	0.13 ha	0.03 ha	1.0 ha	0.13 ha	0.03 ha
Blackbear	89.4	84.1	89.7	75.0	77.1	55.1	75.8	72.1	**47.6**
Upper Grain	73.5	66.1	65.2	75.0	56.5	52.6	74.1	64.3	55.2
Lower Grain	66.2	56.4	**37.5**	72.3	**39.6**	**13.7**	57.6	52.9	**37.3**
All sites	76.6	69.1	64.7	74.1	58.0	40.6	64.9	61.1	46.7

TABLE 3 *Five-year height growth (1999 height minus planting height in centimetres)*

	Subalpine fir			Lodgepole pine			Engelmann spruce		
Site	1.0 ha	0.13 ha	0.03 ha	1.0 ha	0.13 ha	0.03 ha	1.0 ha	0.13 ha	0.03 ha
Blackbear	29.9	28.0	22.6	53.2	39.8	30.0	29.1	29.0	22.3
Upper Grain	17.8	12.7	10.8	38.1	25.3	22.5	23.2	18.6	15.8
Lower Grain	16.1	11.0	9.3	41.3	18.7	15.7	19.7	14.3	12.4
All sites	22.2	18.7	16.1	42.2	30.3	25.3	24.1	21.5	17.1

Windthrow

A total of 43 trees have fallen over in the past 4.5 years, representing 3.4% of the total number of trees permanently marked on the windthrow transect lines. Of these trees, 81% were dead before falling (2 spruce and 33 subalpine fir), and the few live trees (2 spruce and 5 subalpine fir) were scattered over the treatment units. The least windthrow occurred in the uncut control areas (2.6%) compared to the small (3.2%), medium (4.1%), and large (4.2%) treatment units. The data indicate that the weaker dead trees are falling at a slightly higher rate in the harvested treatment units than found in uncut forest.

SUMMARY

The replicated trial provided encouraging information and indicated some areas of concern. Very small openings and very high-elevation sites may be especially challenging to regenerate artificially, but larger openings (over 0.1 ha), especially at the lower elevations, are currently regenerating adequately. Natural regeneration may be a suitable option in years of abundant cone and seed production, but not in other years. Overall, this group-selection silvicultural system seems a viable option for both timber management and maintaining caribou habitat. Further testing of this system during the adaptive management phase will help to refine management techniques.

REFERENCES

Province of British Columbia. 1995. The Cariboo-Chilcotin land-use plan 90-day implementation process. Victoria, B.C. Final report.

Stathers, R.J. 1999. Group selection systems for high elevation ESSFwc3 forests to maintain caribou habitat in the Cariboo Forest Region: microclimate studies. Research Section, Cariboo Forest Region, B.C. Ministry of Forests, Williams Lake, B.C. Draft report.

AUTHORS

* ***Correspondence to:*** **Teresa A. Newsome**, B.C. Ministry of Forests, Cariboo Forest Region, Research Section, #200–640 Borland Street, Williams Lake, BC V2G 4T1.

E-mail: Teresa.Newsome@gems8.gov.bc.ca

† B.C. Ministry of Forests, Cariboo Forest Region, Research Section

‡ B.C. Ministry of Forests, Cariboo Forest Region, Research Section

§ B.C. Ministry of Forests, Cariboo Forest Region, Research Section

From here to eternity: The perils of policy analysis

MARVIN ENG* AND EVELYN HAMILTON†

INTRODUCTION

Technical and scientific support for decision making in the forest policy arena is becoming increasingly important. Policy makers often ask researchers to advise them about what is, or what would be, the impact of alternative resource management policies on a variety of forest values. We present the results of a project that provided scientific support to a policy analysis and some conclusions about how to design research to serve the needs of policy makers.

METHODS

We led a study (Eng and Hamilton 1999) designed to answer the following question posed by policy makers:

> *What is the risk to biodiversity of representing old seral forests at the [Biogeoclimatic Ecosystem Classification] BEC variant level, when establishing landscape unit objectives under the B.C. Forest Practices Code?*

We selected 11 landscape units, throughout British Columbia, that represented a range of ecological and previous forest management conditions, and for which suitable data were available.

We assumed that the procedures outlined in the Landscape Unit Planning Guide (B.C. Ministry of Forests 1999) would be followed when "establishing landscape unit objectives under the Forest Practices Code." Information on the amount of old seral forest that was removed from the timber harvesting land base (e.g., inoperable, low site potential) in each variant, and in each site series in each variant, was compiled.

Given this information and the direction in the planning guide, we determined the extent to which gaps occurred in site series representation, relative to the guide's target levels, when applying the policy of representing old forests at the variant level (referred to as "the policy").

We conducted a pilot risk assessment in two of the landscape units using a two-stage Delphi approach (Richey et al. 1985). In this approach, expert panels of four members used a well-defined process to rate risks to biodiversity.

RESULTS OF THE CASE STUDY

We examined 38 combinations of landscape units and variants. The results fell into four categories of gaps in site series representation that would occur when applying "the policy" (Figure 1).

CITATION —

Eng, M.A. and E.H. Hamilton. 2000. From here to eternity: the perils of policy analysis. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 55–8.

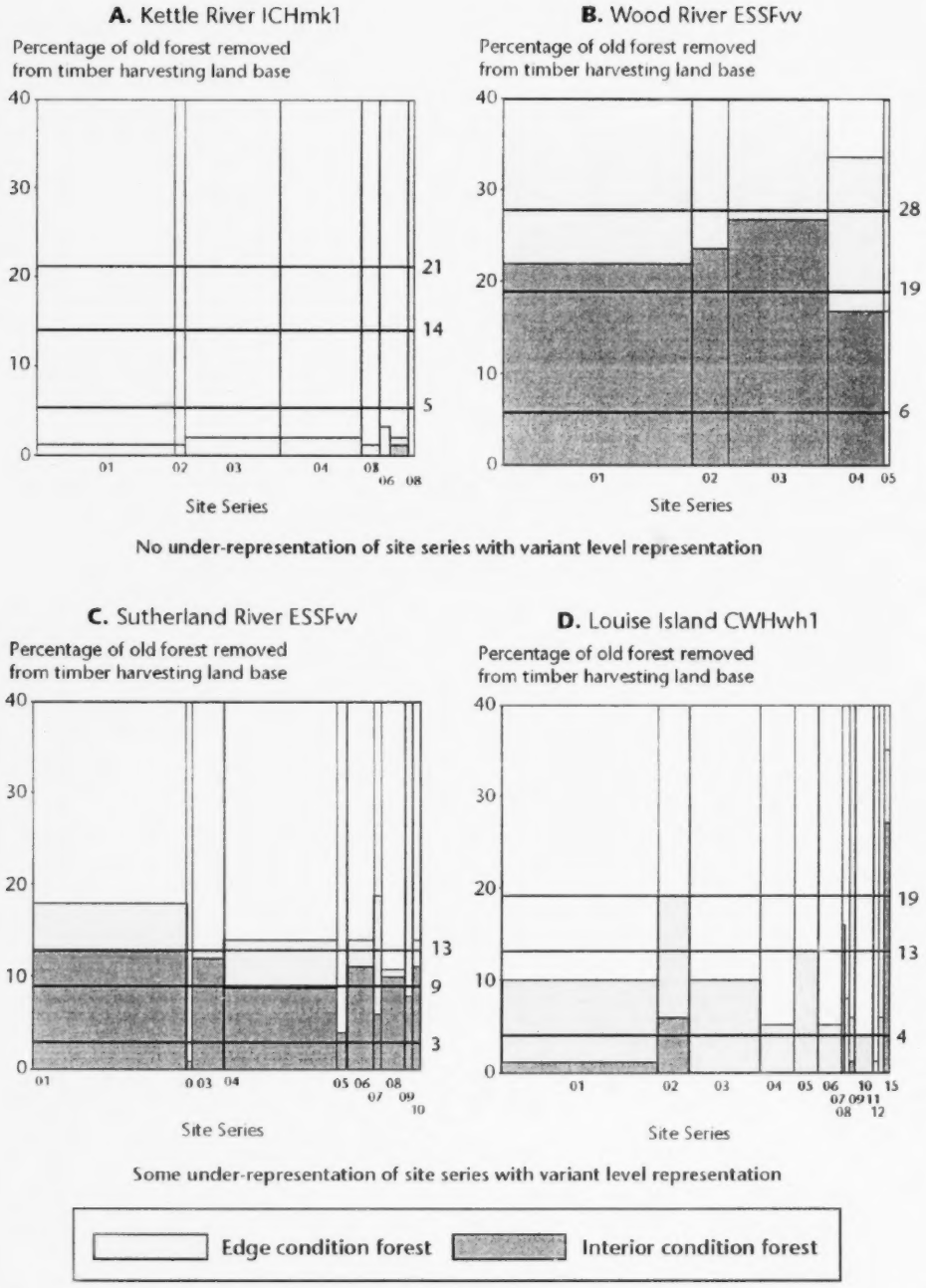

FIGURE 1 *Examples of the four categories of results. Each box represents 40% of the forested area of the variant in the landscape unit (named above the box). The vertical lines separate site series in proportion to their abundance. The three horizontal lines represent percentage targets for old seral representation for each of three biodiversity options. The shaded areas show the amount of each site series that has been removed from the timber harvesting land base.*

In two of the categories (26 of 38 cases), *no* gaps would occur in site series representation if "the policy" was applied. The old forest removals from the timber harvesting land base in these cases were evenly distributed among site series (see Figure 1A and 1B). In one of the categories (6 of 38 cases), some site series with small areas would be under-represented by "the policy" (Figure 1C). Planning options would be limited when dealing with this under-representation since the amount of old forest removed from the harvesting land base would exceed the higher biodiversity-emphasis option target for the variant. Finally, in another 6 of 38 cases, some site series would receive a slight under-representation if "the policy" were applied because some site series are "over-represented" in the areas removed from the harvesting land base (Figure 1D). In these cases, however, planners could decide which site series would be under-represented in a final plan, under some biodiversity emphasis options. This is because the amount of old forest removed from the harvesting land base is less than the target for some options.

The pilot risk assessment did not achieve a consensus on the risk to biodiversity of "the policy" in the two landscape units that were examined. We discuss the reasons for this below.

CONCLUSIONS

The results of this case study (Eng and Hamilton 1999), and the process of conducting the study, highlight conclusions that we believe are generally applicable when providing science support for the analysis of natural resource management policy.

Clearly Specify the Compared Policy Alternatives

The analysis of a given policy's impact requires that it be compared to some other clearly defined policy. However, new policies are often specified because the existing policy environment is uncertain. In this case, the task was "to assess the risk that this direction [variant level representation] poses to biodiversity values" (Pedersen 1998). This begs the question: compared to what *other* direction? Specifying exactly what the policy was compared against and how that comparison was framed was difficult "because of lack of clarity on how to consider representativeness" (Pedersen 1998) before the issuance of the direction. Numerous discussions were required with policy makers to specify an acceptable alternative with which to compare to the existing policy.

Place the Policy Alternatives in Their Appropriate Context

Individual policies invariably exist in a complex policy matrix. It is difficult, and may be impossible, to assess the effect of single policies out of context. When the expert panel attempted to assess the incremental risk of the policy of variant level representation, the result varied widely among the assessors. No consensus on the risk was achieved. We believe that this occurred in part because the panel lacked a common view of the risk to biodiversity of all other current forest management practices. Consequently, assessors were starting from different "baseline" conditions when they assessed the incremental risk.

This contributed to the lack of consensus since there is no reason to suspect that risk to biodiversity increases in a linear fashion with increasing management impact. In fact, the metaphor of "straw that broke the camel's back" represents a commonly held belief about management impact. Therefore, depending on where one believes we are on the management impact continuum, relative to some threshold, very different assessments of incremental risk can result from identical "additions" to management impact.

Identify Meaningful and Measurable Response Variables

Analysis of natural resource values is complicated by the fact that many are "concept clusters" (*sensu* Peters 1991). We had to extract a measurable response variable from one of the largest concept

clusters—biodiversity. We chose site series representation because, as one method of defining ecosystems (Meidinger and Pojar 1991), site series are explicitly part of the definition of biodiversity (B.C. Ministry of Forests 1999) and a reasonably well-understood relationship exists between site series and other aspects of biodiversity. This choice was the result of an iterative process conducted with policy makers and stakeholders during which a number of variables were examined. We note that the choice of a response variable is not a purely objective exercise; the choice, itself, influences the outcome.

In conclusion, we expect that the most difficult parts of developing a study design for scientific support to policy analysis will be:

- defining clearly the policy alternatives to be compared;
- placing them correctly in the context of the overall policy environment; and
- identifying meaningful and measurable response variables.

These steps may require several iterations with policy makers and possibly with interested stakeholders.

REFERENCES

B.C. Ministry of Forests. 1999. Landscape unit planning guide. B.C. Ministry of Forests, Victoria, B.C.

Eng, M.A. and E. Hamilton. 1999. An analysis of the policy of variant level old forest representation. B.C. Ministry of Forests, Research Branch, http://www.for.gov.bc.ca/research/repbyvar

Meidinger, D. and J. Pojar. 1991. Ecosystems of British Columbia. B.C. Ministry of Forests, Research Branch, Victoria, B.C. Special Report No. 6.

Pedersen, L. 1998. Chief Foresters direction on landscape unit planning. B.C. Ministry of Forests. Memorandum File: 12500-02, May 28, 1998.

Peters, R.H. 1991. A critique of ecology. Cambridge University Press, Cambridge, UK.

Richey, J.S., R.R. Horner, and B.W. Mar. 1985. The Delphi technique in environmental management. II. Consensus on critical issues in environmental monitoring and design. Journal of Environmental Management 21:147–59.

AUTHORS

* ***Correspondence to:*** **Marvin A. Eng**, B.C. Ministry of Forests, Research Branch, PO Box 9519 Stn Prov Govt, Victoria BC V8W 9C2.

E-mail: Marvin.Eng@gems5.gov.bc.ca

† B.C. Ministry of Forests, Research Branch

Designing an adaptive management field project: A case study

VERA SIT* AND BRIAN NYBERG†

INTRODUCTION

As more forest managers adopt the notion of adaptive management as a way of responding to changing expectations and uncertain knowledge, they face the challenge of turning what to many is a fuzzy concept into real-life practice. One of the tasks many managers find difficult is designing field experiments, often called operational trials. These experiments are one of the essential components of the systematic adaptive management process of learning from the outcomes of operational policies and practices, but they are not the typical focus of an operational manager's work. Here we point out some of the issues managers should consider in designing field experiments, and provide some advice on how to deal with the stickier problems.

CASE STUDY

Throughout British Columbia, foresters and biologists are trying to determine the best harvesting and silvicultural practices to apply to riparian areas along small streams. Streams designated as "S4" under the Forest Practices Code—the smallest (< 1.5-m wide) fish-bearing streams—are particularly challenging. In the central Interior, for example, the Code states that the best management practice for these streams is to retain all trees within 10 m of the stream bank, except where windthrow hazard is moderate to high (see Table 11 in the *Riparian Management Area Guidebook*). However, because many areas on the interior plateau experience frequent strong winds, logging companies remove all merchantable trees along many S4 streams in their cutblocks. This has raised concerns that some of the ecological functions of streamside trees and other vegetation are being lost, to the detriment of the stream, its fish, and other aquatic organisms.

In the Prince George Forest District, the district manager recently issued a policy to guide foresters in writing prescriptions for harvesting and silvicultural practices along S4 streams. The policy is intended to protect S4 stream and riparian conditions, while recognizing the risk of windthrow. This policy introduces the notion of managing for retention of a high percentage of natural shade along the stream, and for continuing the periodic recruitment of large organic debris in the riparian area in both the short and long term.

The Prince George Forest District is committed to the monitoring and evaluating of this new policy to ensure that it achieves both ecological and timber management goals. District staff and a group of local and Victoria co-operators, including staff from Research Branch and Forest Practices Branch, are developing an adaptive management approach to evaluate the S4 stream guidelines. The important

CITATION —

Sit, V. and B. Nyberg. 2000. Designing an adaptive management field project: a case study. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 59–62.

question in the evaluation is: how successful is the district manager's policy in protecting the stream and riparian values, compared to:

- leaving a 10-m reserve zone;
- harvesting all merchantable trees, while still providing a 5-m "machine-free" zone adjacent to the stream and retaining non-merchantable vegetation; or
- not logging at all.

These alternatives can be considered to be four treatments (called District Manager's Policy, 10-m Reserve, Clearcutting, and Control). The concept for the adaptive management project is to test these alternative treatments in the Prince George District by using operational logging activities planned through the co-operation of local forest companies and the Small Business program. Stream temperature, post-logging shade, large organic debris level, and windthrow are the indicator variables that would be monitored to assess the suitability of the various treatments.

We used the design of an operational test of these riparian management alternatives to illustrate some of the many questions that should be considered by managers who want to conduct operational trials or management experiments. For this discussion, we will simplify the Prince George situation by ignoring the details of study site selection and monitoring designs.

DESIGNING THE ADAPTIVE MANAGEMENT STUDY

Ideally, we would want to design our study to produce the most reliable and informative results. To a statistician this means: minimum variation between experimental units, lots of replications, and fully randomized treatments with a proper control. These requirements can often be met in small-scale experiments performed in a controlled environment, but are not always possible in an operational setting where factors such as expense, feasibility, and efficiency need to be considered. In the Prince George adaptive management study, we tried to plan a rigorous study in a very variable environment with limited resources.

To minimize variability in the experimental units, it is necessary to stratify the streams by forest type and stream gradient. With four forest types (various mixes and structures of lodgepole pine and spruce), three stream gradients (< 2% slope, 2–10%, and > 10%), and four treatments, we would need 144 streams for three replications, or 240 streams for five replications. From the lead author's experience in reviewing many research proposals, three replications seems to be the Forest Service norm for minimum number of replications, but three is really not enough, particularly for systems with large unknown variations. To reduce the number of streams sampled, we recommended narrowing the scope of the study to two forest types (the extremes: single-storey pine and multistorey spruce mix), and two stream gradients (moderate: 2–10% slope; low: < 2% slope). We, therefore, chose between getting a little data on many strata, and much more data on fewer strata.

We then considered treatment layout. We could arrange all four treatments sequentially along a stream, or apply one treatment to each stream. We abandoned the single-stream design because it would require deliberately setting all four treatments along the same stream. This could prove difficult because it might not be possible to accommodate all four treatments along a stream, or each stream section might have different forest type or gradient. In addition, we recognized that the operational setting of the work is more suited to using only one stream treatment in each cutblock, rather than multiple treatments as might be the case in a more traditional scientific research design. We decided to apply each treatment to an entire stream segment within a cutblock with an upstream control. This, in effect, reduced the number of treatments to three. This layout would allow us to assess the effects of each treatment and compare the effects between the three treatments. We still need 60 streams for five replications.

Bearing in mind the logistic difficulties of finding suitable streams and prescribing the required treatments, it is quite impossible to get enough streams in one field season, and the cost would be enormous. One solution is to run the study over at least 3 years. We could find some streams for each forest type or stream gradient each year, but we should include all treatments in each year to allow proper analysis by year.

We have recommended a "Before/After Control Impact" design for this study to properly evaluate the effects of the three treatments. Because clearcutting is not recommended as a riparian prescription for S4 streams under the district manager's policy, we considered using already-logged streams for the clearcut treatment. We decided not to compromise the design this way, however, because the after-treatment data would be of doubtful value without the before-treatment data. Another solution to the problem is available: the clearcut treatment is already routinely applied to S6 (small non-fish bearing) streams. We can thus find appropriate S6 streams similar to S4 streams in all respects, except for fish presence.

To reduce cost, we restricted the number of measured variables. We also tried to find monitoring methods that would minimize field time. For instance—

- Stream temperature can be assessed using temperature sensors that store a year's data.
- Shade over the stream need only be assessed once a year.
- Channel structure and large organic debris can be assessed using overhead photographs taken with a camera on a long pole.

To ensure that the collected data would meet the study's objectives, we examined our analysis options. The study design considerations that we weighed are summarized in Table 1.

TABLE 1 *Design considerations*

Features we stand firm on:	Compromises we made:
• Have sufficient number of replications	• Span study over several years
• Maintain the range of treatments to be tested	• Narrow the scope of the study
• Require before and after sampling	• Use S6 streams instead of S4 streams
• Measure the important variables affecting future decisions	• Reduce the number of indicator variables

CONCLUSIONS

1. It is feasible to establish an adaptive management study to test management policy in an operational setting.
2. Do not do it alone. Get a helpful statistician involved at the beginning of a study.
3. "Policies are experiments; *learn from them*" (Kai Lee 1993).

REFERENCES

Lee, Kai. 1993. Compass and gyroscope: Integrating science and politics for the environment. Island Press, Washington, DC.

AUTHORS

* ***Correspondence to:*** **Vera Sit,** BC Ministry of Forests, Research Branch, PO Box 9519 Stn Prov Govt, Victoria, BC V8W 9C2.

E-mail: vera.sit@gems5.gov.bc.ca

† B.C. Ministry of Forests, Forest Practices Branch

GIS and the visualization of First Nations resource management

JOHN LEWIS*

People's uses of, responses to, and bonds with their environment differ from one person to the next, although at times it is possible to make some generalizations based on a clustering of individual's knowledge and experiences. In this way, we can talk about group knowledge and experience, perhaps reflecting distinctive cultural experiences. Various methods have been used to develop an understanding of environmental knowledge, including questionnaires, formal or informal interviews, and document analysis, as well as observing and making inferences from patterns of use. Obtaining information about environmental knowledge becomes complex when people of different culture and contrasting heritage are involved.

The purpose of this research was to explore the role of new and emerging technologies, such as GIS resource mapping and three-dimensional visualization, in forest and land management processes involving First Nations. The research is based on two considerations. First, the recent court decisions upholding the inherent right and title of First Nations to natural resources (e.g., *R.* v *Sparrow* and *R.* v *Delgamuukw*) have placed First Nations at the forefront of resource management issues in British Columbia. Throughout British Columbia, First Nations groups are becoming increasingly involved in the use of GIS and visualization technology in both land claims and the management of resources. In the words of the Gitksan Strategic Watershed Analysis Team: "We identify the resources we need, and we create a common language built of maps and jargon, data and dialect that fuses the best of ancient wisdoms and modern technology." The second consideration involves the severe deficiency of the conventional tools (i.e., two-dimensional planimetric maps) employed by forest planners to consult with indigenous groups and communicate landscape management proposals. Aboriginal perceptions of the land and environment are highly integrated, but in the process of placing environmental values in standard cartographic format, much of value may be lost. Apart from the difficulties of adequately depicting thematic information, an added difficulty may be that of understanding symbolism such as contour lines. Ability to read and understand cartographic devices such as contour lines and mentally reconstruct topography from them is taken for granted by those who frequently use conventional maps. In reality, relatively few people can look at a conventional map and mentally reconstruct the landscape that it represents. However, indigenous peoples must have a clear picture of how land management proposals (e.g., timber harvesting, watershed restoration), depicted on conventional maps, would appear in the real world.

Emerging techniques involving computer-based visual information systems such as user-friendly GIS resource mapping and three-dimensional visualization, offer new ways to interact with landscape information and, perhaps, to measure more deeply rooted indigenous environmental perceptions.

CITATION —

Lewis, J. 2000. GIS and the visualization of First Nations resource management. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 63–4.

However, little is known about how useful or acceptable these innovative tools are for different cultural groups, or whether they can help communicate land-use information and perceptions of land-use management. This research initiative:

- examines this evolving cross-disciplinary area;
- assesses the potential utility of integrated GIS and three-dimensional visualization technology as a resource management tool; and
- analyzes the utility of this technology on a watershed-based resource management project led by the Cheam First Nation of the Pilalt tribal group.

A component of this research examines current techniques for calibrating and integrating watershed management data and restoration prescriptions into the GIS/visualization model to develop a range of alternative watershed management visualizations. The visualizations will be presented to members of the Cheam First Nation and used as a basis for mapping traditional ecological knowledge, and for eliciting their reactions to the management scenarios and visual medium.

AUTHOR

* ***Correspondence to:*** **John Lewis**, University of British Columbia, 2045–2424 Main Mall, Vancouver, BC V6T 1A4.

E-mail: johnlew@interchange.ubc.ca

An innovative approach to extending knowledge

TRINA INNES*

INTRODUCTION

The British Columbia Journal of Ecosystems and Management (JEM) is a new electronic journal published by the Southern Interior Forest Extension and Research Partnership. JEM integrates ecological and socioeconomic research and operational experience to support informed sustainable management decisions in British Columbia. Designed for practitioners, professionals, researchers, agencies, decision-makers and natural resource users, JEM will share scientific results, successful management applications, socioeconomic analysis, scholarly opinions, and operational and traditional knowledge.

JEM is innovative and unique from other journals. It will:

1. Focus on provincial research, practical land management experience, and management implications.
2. Publish original, peer-reviewed articles refocused in popular language.
3. Deliver content requested by our audience, including syntheses of research information, science-based evaluations and recommendations, technology transfer, views on public policy and natural resource issues, and research needs.
4. Offer assistance to organizations and individuals to maximize the delivery of information.
5. Provide efficient and rapid publication of papers.
6. Provide free, unlimited access and downloading of articles published online (print copies will also be produced for limited distribution).
7. Provide an interactive online forum that allows for follow-up discussion of published papers.
8. Pursue the potential of electronic information technology for sharing information.

WHAT TOPICS WILL JEM PUBLISH?

The journal welcomes contributions on all topics relating to research and management of British Columbia's ecosystems. Papers will focus on issues of current interest to the natural resource community, research results of a high scientific standard, and innovative practices. Topics may include:

- Community development
- Conservation biology
- Culture
- Decision-support tools
- Economic development
- Ecosystem management
- Experiential knowledge
- Extension
- First Nations
- Fisheries and aquatic resources
- Forest practices
- Geomorphology
- Grasslands
- Hydrology
- Information management
- Landscape management
- Landscape ecology
- Problem solving
- Range
- Research
- Silviculture
- Socioeconomics
- Soils
- Technology transfer
- Traditional knowledge

CITATION —

Innes, T. 2000. An innovative approach to extending knowledge. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 65–7.

Original papers are welcomed. Previously published papers that have been reworked (i.e., substantially rewritten to meet the goals of JEM) are also invited. Accepted papers will be placed in one of the following sections.

1. News and Views

Commentaries on the current and future status of natural resource management. Papers may state an opinion, offer a challenge, or present a thought-provoking idea on natural resource management issues or articles published in the journal. These papers will not be peer-reviewed, but they will be screened for appropriateness and relevance to the journal and will be subject to a readability edit.

2. Extension Notes

Extension notes focus on simplified syntheses of existing or new research, operational trials, preliminary field results, new tools or technology, and other knowledge areas. Their main purpose is to provide short messages, tools, techniques, results, or knowledge that will improve resource management activities.

3. Knowledge in Action

This section provides brief accounts of how research results have been adopted and placed into practice. It will include progress reports of ongoing research work, invitations for research partnerships, operational application of research knowledge, brief reports on single case studies, and technology developments with management applications.

4. Current Research

Open to full-length scientific research and discussion papers which cover major research projects or programs, develop new concepts in natural resource management, or test ideas with data from field and laboratory experiments, observations, or simulations.

HOW WILL JEM FUNCTION?

All manuscripts that complete the peer-review process and are accepted for publication will immediately be published online in an "Issue-in-Progress." Issues may be closed at any time at the discretion of the Editor. Once an issue is closed, volume, issue, and page numbers will be assigned, and a limited number of print copies of the journal will be distributed to major repositories.

Primarily Web-based, the journal will be issued in annual volumes—two to four issues are planned for each volume. Online readers will be able to view and download the content of individual papers and issues. The abstract, author, title, and keywords for each paper will be archived in a searchable online database. Readers may register for online notification of new issues.

MEMBERS OF THE ADVISORY PANEL

As the voice of the readership, the panel helps ensure that the journal addresses the needs of our readers. They advise on editorial strategy, suggest future content ideas, and help solicit high-calibre papers. The advisory panel consists of:

- **Steve Arndt**, Columbia Basin Fish and Wildlife Compensation Program
- **Tan Calhoun**, Babine Forest Products Company

- **Rob D'Eon**, Kokanee Forests Consulting
- **Susan Hall**, Parks Canada
- **Chris Hollstedt**, Southern Interior Forest Extension and Research Partnership
- **John Innes**, University of British Columbia
- **Colin James**, University College of the Cariboo
- **Nancy Levesque**, University College of the Cariboo
- **Julie MacDougall**, Forest Practices Branch, B.C. Ministry of Forests
- **David Meers**, British Columbia Institute of Technology
- **Thomas Munson**, Ktunaxa/Kinbasket Tribal Council
- **Reg Newman**, Research Branch, B.C. Ministry of Forests
- **Brian Robinson**, Industrial Forestry Service Ltd. and Association of British Columbia Professional Foresters
- **Gordon Weetman**, University of British Columbia

PEER REVIEW

If the content of the article is appropriate and in an acceptable format, the Review Committee will assign the article to a peer review. After the submission has been reviewed, final decisions on acceptance, revision, or rejection will be made by the Editor. In general, all papers will be reviewed by two individuals with skills relating to the paper, one member of the natural resource community and one Partnership Extension Specialist.

SUBMITTING A PAPER

Draft manuscripts for the journal are accepted on an ongoing basis. The Partnership's Review Committee will evaluate the submission for content suitability. If accepted, the draft manuscript will be subjected to peer review. Authors should consult the journal's "Guidelines to Authors" before submitting their documents. Draft manuscripts and other inquiries may be submitted by fax, mail, or e-mail to the Managing Editor.

AUTHOR

* ***Correspondence to:*** **Trina Innes**, Managing Editor, BC Journal of Ecosystems and Management, c/o SIFERP, Box 3010, Division of Sciences, University College of the Cariboo, Kamloops, BC V2C 5N3.

E-mail: trina.innes@siferp.org

First-season growth of lodgepole pine seedlings grown in three different container types and planted on landings, or on burned or unburned sites

MELANIE JONES*, ANNE JOHNSON-FLANAGAN†, STEVEN KIISKILA‡, AND CHARLES BULMER§

INTRODUCTION

Good root growth following outplanting is important, but it does not always occur, especially on difficult sites. Most conifer seedlings produced in British Columbia are grown in Styrofoam® containers with conical cavities. In the nursery, major roots grow down the sides of untreated cavities and consequently, most new root growth following outplanting occurs from the bottom of the plug (Balisky et al. 1995). These roots emerge into soils that are colder and have lower nutrient levels than soils closer to the surface. This is a problem especially for lodgepole pine (*Pinus contorta* Dougl. ex Loud.) seedlings because they do not produce adventitious roots from the root collar (Balisky et al. 1995). To overcome this problem, most lodgepole pine seedlings produced in the province are now grown in copper-treated Styrofoam containers. The copper arrests the growth of the roots when they hit the sides of the cavity. Following outplanting, new roots extend laterally out from the sides of the plug, rather than straight down from the bottom.

In the last several years, concerns have been raised about copper leaching into water supplies from the treated styroblocks. Newly introduced containers have cavities with vertical slits. These air-vent blocks are intended to air-prune the roots as they reach the edge of the cavity. The major objective of this study was to evaluate the development and field performance of pine seedlings grown in air-vent blocks compared to those grown in untreated and copper-treated styroblocks, using both morphological and physiological criteria. Seedlings were planted in different rooting environments to determine whether root system development was differentially affected by container type in the different environments.

Many morphological and physiological criteria have been used as indicators of nursery stock quality, but tests currently used operationally are not sophisticated enough to correlate with field performance (Mohammed 1997). We have selected several tests which measure performance attributes, such as drought stress resistance, root growth capacity, and root viability (Mattsson 1997) to determine whether they can be used to predict field performance.

MATERIALS AND METHODS

Lodgepole pine seedlings were grown outdoors from April to November in untreated Styrofoam containers, copper-treated Styrofoam containers, or plastic air-vent containers. "Copper" seedlings were

Citation —

Jones, M.D., A.M. Johnson-Flanagan, S.B.R. Kiiskila, and C. Bulmer. 2000. First-season growth of lodgepole pine seedlings grown in three different container types and planted on landings, or on burned or unburned sites. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 69–72.

given photoperiod extension to 21 hours for 5 weeks to encourage the development of secondary needles. Seedlings grown in copper blocks were separated into those with primary needles (copper-1) and those that had developed secondary needles (copper-2). All other stock types had primary needles only. Following lifting, seedlings were stored at 2°C in the dark for 27 weeks.

In March, 1998, 30 randomly selected seedlings of each type were removed from cold storage and tested for:

- root carbohydrate status;
- drought tolerance;
- root viability (triphenyl tetrazolium chloride [TTC], Steponkus and Lanphear [1967]); and
- location of active root apical meristems (Root Growth Capacity test: 10 days at 24°C, with watering to run-off every 3 days).

In May, 1998, 50 seedlings of each stock type were planted into three replicate plots in each of three planting environments: screefed microsites; burned, unscreefed sites; and ripped landings. In September, 1998, shoot height and root collar diameters of 20 seedlings per treatment per plot were assessed. Data were analyzed by one-factor or two-factor ANOVA.

RESULTS AND DISCUSSION

- Root viability, as measured by TTC, was highest in root systems grown in the air-vent containers and lowest in untreated Styrofoam containers ($p < 0.0001$).
- The air-vent containers were even more effective than copper-treated blocks in allowing root egress from the top of the plug (Figure 1). The total number of new white roots produced was not affected ($p < 0.05$) by container type.
- Injury from drought stress was lowest in primary-needle seedlings from the copper-treated

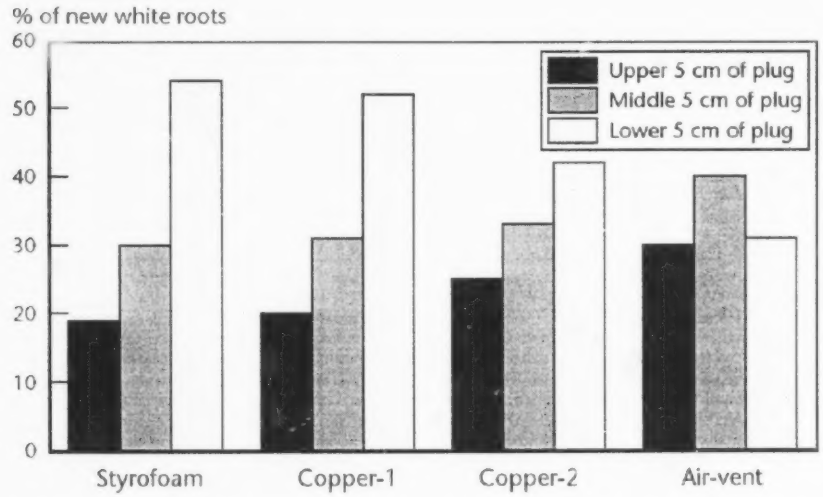

FIGURE 1 *Location of new root growth after 10 days under optimal conditions (Root Growth Capacity test). A one-factor ANOVA detected differences amongst containers at* $p < 0.0001$ *for each location.*

containers. Injury in air-vent seedlings was similar to that of the other three groups of seedlings ($p = 0.03$ for % needle injury; $p = 0.006$ for % root injury).

- Differences in response to drought stress were not due to differences in the levels of total soluble carbohydrates or starch in the roots of the seedlings. No differences were detected in these variables ($p < 0.05$).
- After one season of growth in the field, air-vent and primary-needle copper seedlings were taller than secondary-needle copper seedlings or seedlings grown in untreated Styrofoam containers (Table 1). No differences in root collar diameter were observed.
- Seedlings planted on the cutblock grew better than seedlings on the landings; the differences in needle length were especially marked (Table 1). Needle length was longer on burned sites than on screefed unburned microsites. There were no interactions between container type and planting location.

Our interim conclusions from the first part of this study are that the air-vent containers would be an appropriate substitute for copper-treated Styrofoam. Seedlings grown in these containers were comparable to, or better than, copper seedlings in root distribution and shoot growth in the field. Root viability, as measured by TTC, was the best predictor of height increment during the first growing season. Root carbohydrate status and drought stress resistance were poor predictors.

The next phase of the project tests interactions between microbial inoculants and container types, and will compare growth on rehabilitated and non-rehabilitated landings.

ACKNOWLEDGEMENTS

Forest Renewal British Columbia and Weyerhaeuser Canada provided funding for this research. Seedlings were grown by Pacific Regeneration Technologies, Vernon.

TABLE 1 *Field assessment of lodgepole pine seedlings planted in late May, 1998 on screefed unburned or unscreefed burned sites, or on ripped landings. Assessments took place in early September, 1998*[a].

Stock/ treatment	Height at planting (cm)	Height increment (cm)	Total height (cm)	Root collar diameter (mm)	Distal needle length (cm)
PAB-1[b]	13.9 ± 0.4 a	10.5 ± 0.4 a	29.6 ± 0.7 a	4.9 ± 0.1	5.2 ± 0.5
PCT-1[c]	13.0 ± 0.8 b	10.3 ± 0.6 ab	28.7 ± 1.0 a	4.9 ± 0.1	5.3 ± 0.5
PCT-2[d]	10.6 ± 0.2 c	10.8 ± 0.5 a	26.8 ± 1.0 b	4.9 ± 0.1	5.4 ± 0.4
PSB-1[e]	12.5 ± 0.3 b	9.1 ± 0.5 b	27.1 ± 0.9 b	4.8 ± 0.1	5.5 ± 0.4
p[f]	0.0011	0.0020	0.0022	0.50	0.76
Screefed	12.3 ± 0.5	10.8 ± 0.4 a	29.2 ± 0.5 a	5.0 ± 0.1 a	6.0 ± 0.3 b
Burned	12.7 ± 0.6	10.1 ± 0.3 a	29.4 ± 0.6 a	5.1 ± 0.1 a	6.7 ± 0.2 a
Landings	12.4 ± 0.6	8.1 ± 0.2 b	24.1 ± 0.6 b	4.6 ± 0.0 b	3.6 ± 0.1 c
p[f]	0.85	0.0001	0.0001	0.0001	0.0001

a Within a column, numbers followed by different letters differ at $p = 0.05$.
b Seedlings grown in air-vent blocks.
c Seedlings grown in copper-treated styroblocks under extended photoperiod; had primary needles at lifting.
d Seedlings grown in copper-treated styroblocks under extended photoperiod; had secondary needles at lifting.
e Seedlings grown in untreated styroblocks.
f Results of two-way analyses of variance, with stock type and planting location as factors; no significant interactions between the two factors.

REFERENCES

Balisky, A.C. 1995. Seedling roots and forest floor: misplaced and neglected aspects of British Columbia's reforestation effort? Forestry Chronicle 71:59–65.

Mattsson, A. 1997. Predicting field performance using seedling quality assessment. New Forests 13:227–52.

Mohammed, G.A. 1997. The status and future of stock quality testing. New Forests 13:491–514.

Steponkus, P.L. and F.O. Lanphear. 1967. Refinement of the triphenyl tetrazolium chloride method of determining cold injury. Plant Physiology 42:1423–6.

AUTHORS

* ***Correspondence to:*** **Melanie D. Jones**, Okanagan University College, 3333 College Way, Kelowna BC V1V 1V7.

E-mail: mjones@okanagan.bc.ca

† University of Alberta, Edmonton, Alberta

‡ Pacific Regeneration Technologies, Vernon, B.C.

§ B.C. Ministry of Forests, Research Branch

Brushing for future forests or free-growing requirements?: One to five year PROBE results

SUZANNE SIMARD*, JEAN HEINEMAN†, AND JEAN MATHER‡

INTRODUCTION

The legislation governing free-growing status sets out to ensure that plantations reverting from the licensee to the Crown are satisfactorily regenerated and are unlikely to require further significant interventions until maturity. The fundamental principle involved here is that "competition with plants, shrubs, or other trees" has a negative influence on survival and growth of young conifers, and has motivated extensive brushing of juvenile stands at substantial cost to the forest industry. This is expected to increase as more plantations approach the free-growing stage.

Although substantial money and effort has been expended for brushing treatments across the province, little has been spent on monitoring the effectiveness of these treatments. Furthermore, the underlying principle that native plant communities are indeed detrimental to conifer survival and growth has not been tested. One exception is the PROBE program (Protocol for Operational Brushing Evaluations, Simard [1993]) as applied in the Kamloops and Nelson Forest Regions.

MATERIALS AND METHODS

PROBE was designed to study the effects of vegetation management treatments on conifer survival and growth, and on the structure, diversity, and condition of the vegetation community. These effects are measured in operationally brushed clearcuts. Each PROBE installation consists of a treatment plot (treated operationally with the rest of the opening) and a control (area left untreated in the same opening) which have similar ecosystem characteristics. Each plot is about 0.8 ha in size. Thirty-six crop tree-centred subplots are established on a grid within each of the treatment and control plots. Within each subplot, crop tree size, condition, and degree of overtopping, as well as height and cover of the dominant species and vegetation groups are assessed before the brushing treatment. In four of these subplots, the cover and height class of all vascular plant species are also recorded. These measurements are repeated 1, 3, 5, and 10 years after treatment.

Sites that have the same biogeoclimatic zone, vegetation complex, conifer species, and similar brushing treatment are grouped together for analysis. A minimum of three replicates is required for analysis of variance and regression analysis. Results for fully replicated treatment cells are currently available for eight complexes.

Because PROBE monitors operational treatments, it includes more variable site and treatment conditions than normally occur in strictly controlled research studies. This is reflected in the results. There are

Citation —

Simard, S.W., J.L. Heineman, and W.J. Mather. 2000. Brushing for future forests or free-growing requirements?: one to five year PROBE results. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 73–5.

several reasons why PROBE may not show significant brushing responses, when comparable, strictly controlled experiments do. For instance—

- Operational treatments are not always uniform, nor do they test "complete vegetation removal" treatments.
- PROBE monitors a wider range of site conditions and stand ages.
- Operationally brushed plantations include a wide range in vegetation density, whereas experiments are usually conducted on high-brush-density sites.

Each approach has advantages: PROBE provides a more accurate picture of operational brushing efficacy, whereas research experiments often investigate "potential" responses and the underlying mechanisms.

RESULTS AND DISCUSSION

Our 1–5 year results show that, on many sites deemed in need of operational brushing, conifers survived and grew as well in the untreated controls as they did in the brushing treatments. In some cases, this was because the brushing treatment had only a short-lived effect on vegetation (e.g., a single manual cutting treatment applied to the Fireweed Complex). At other sites, however, the lack of response was because seedlings were not experiencing deleterious competition (e.g., lodgepole pine in the Dry Alder complex). Survival was not improved by manual or chemical brushing in any of the complexes studied, and actually declined in the Mixed Hardwood-Shrub complex because of Armillaria root disease following manual cutting and girdling. In many cases, mortality was the result of factors other than interspecific competition, and in others, brushing did not reduce brush abundance below survival thresholds.

The effect of brushing on growth has been more variable than the effect on survival. It has improved height or diameter growth in one-half of the complexes studied, and had no effect in the others. In particular, we have found that:

- Brushing improved conifer growth in some Interior Cedar–Hemlock (ICH) complexes (Fern, Mixed Hardwood Shrub, Mixed Shrub) and in the Engelmann Spruce–Subalpine Fir (ESSF) Ericaceous Shrub complex. Our individual tree data indicate that: not all trees were suppressed by competition in these complexes; not all trees responded to brushing; and selective treatment of stressed trees would likely have achieved similar responses in average or top height growth.
- Brushing had no effect in any of the dry-belt complexes (Aspen, Dry Alder, Willow, Pinegrass) or in the high-elevation complexes that tend to occur on subhygric ESSF sites (Subalpine Herb, Wet Alder). Note that PROBE has only partial replication of Willow and Pinegrass, but our trends are corroborated by other published studies.
- A single manual cutting improved conifer growth in the ICH Mixed Hardwood-Shrub, Mixed Shrub, and Ericaceous Shrub complexes, but was ineffective in the remaining four complexes tested.
- Glyphosate, applied either as a spray or cut-stump treatment, improved conifer growth in the ESSF Fireweed complex, as well as the ICH Fern and Mixed Hardwood-Shrub complexes.
- A single sheep-grazing treatment had no effect on seedling growth in the ICH Mixed Shrub complex.

Brushing effects on plant communities depended on the brushing method applied. In general, a single manual cutting treatment had little effect on the herbaceous and low-elevation shrubby complexes, and reduced structural diversity only slightly in the Ericaceous Shrub complex. In contrast, manual cutting substantially altered structure of the broadleaf complexes. Glyphosate also changed community

structure and diversity regardless of where it was applied. Sheep grazing altered the plant communities in the short term, including reductions in structural diversity and shifts in plant community composition.

In summary, our short-term results show that operational brushing makes biological sense in some complexes, but in many it is ineffective at improving survival or growth of conifers. Whether the observed short-term growth responses are sustained, affect rotation lengths, or affect stand yield or value, can only be determined with long-term monitoring. Although our results generally concur with the limited literature, conifer responses were sometimes lower than those measured in research experiments. This is attributed to the lower brush densities and greater variability in treatment efficacy, tree growth, site conditions, and stand ages normally encountered in operations. Our results suggest that brushing is frequently applied where it is unnecessary, and for some complexes, the single manual treatments commonly applied are ineffective. We feel that the free-growing standard overemphasizes the importance and severity of plant competition in several southern Interior vegetation complexes, and that free-growing legislation should be changed to give professional foresters more flexibility to prescribe brushing only where needed. Eliminating unnecessary brushing treatments would free-up dollars for better identification of deleterious competition, selective treatment of stressed trees only, and intensive management of the most valuable, problematic sites. This could be achieved by shifting the focus of the legislation away from "competing vegetation" and onto the health and performance of the crop trees.

REFERENCES

Simard, S.W. 1993. PROBE: Protocol for operational brushing evaluations (first approximation). B.C. Ministry of Forests, Victoria, B.C. Land Management Report No. 86.

AUTHORS

* ***Correspondence to:*** **Suzanne W. Simard**, B.C. Ministry of Forests, Kamloops Forest Region, 515 Columbia Street, Kamloops, BC V2C 5Z7.

E-mail: Suzanne.Simard@gems9.gov.bc.ca

† Jean Heineman Forestry Consulting

‡ Skyline Forestry Consultants Ltd.

Native grass seed development

MANIVALDE VAARTNOU*

INTRODUCTION

Since the 1970s, there has been considerable interest and support for the use of native species to revegetate disturbed areas. For example, both the reports of the Mackenzie Valley Pipeline Inquiry (1977) and of the Clayquot Sound Scientific Panel (1995) recommended the use of native species in the areas relevant to these reports. Possible benefits of using native species may include any of the following:

- assist in retention of local biodiversity
- create a more harmonious end vista
- increase long-term survival prospects
- improve reseeding potential
- decrease costs through lower fertilization and seeding rates

Other political jurisdictions, such as Australia, Alaska, and much of the contiguous United States, have legislation that requires the use of native species in restoration of public lands. This is not the case in western Canada where vast amounts of introduced grass seed are added annually to our landscape. For instance, on Vancouver Island over 100 000 kg of non-native seed is distributed annually by just two of the major participants in reclamation—the forest industry and the Ministry of Transportation and Highways.

Small projects can collect the seed of "wild flowers," multiply and harvest this seed, and then use it to reseed disturbed areas. The restoration of the Red Heather Meadows and Elfin Lakes areas of Garibaldi Provincial Park was completed in this manner. For most species, however, the cost will be exorbitant. No large-scale user (public or private) operating under budgetary constraints will voluntarily support such a program, except on a few very high-profile locations. Furthermore, the total impact on the amount of non-native seed added to the landscape will be insignificant, whether the seed collected is directly applied to the disturbed area, or whether plants are grown in the field or a greenhouse and then transplanted to the disturbed site. Thus, programs in which minor quantities of native seed are collected from the wild will not solve the overall problem.

The lack of a reliable, cheap source of native seed species has been a major barrier to their large-scale use in British Columbia reclamation programs. This barrier has inhibited the introduction of new legislation that would require the use of native species in restoration of public lands. With grasses, the problem is more one of agricultural economics than plant biology. Native grasses will grow and survive, if the species is appropriate to the region. The questions that need consideration are:

- Will the use of native grasses achieve the goals of any specific reclamation scenario?
- At what cost can reclamation success be achieved?

Citation —

Vaartnou, M. 2000. Native grass seed development. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 77–9.

M. Vaartnou and Associates are involved in two separate programs to answer these questions for Vancouver Island and northwestern Canada, respectively. The long-term objective of these programs is to harvest enough seed from breeders' seed plots to allow established seed companies to, in turn, grow sufficient supplies for large-scale purchasers. The following basic conditions must be met for large-scale users to order native grass seed.

- Sufficient native seed is available for large-scale reclamation.
- Trial results for the native species plots are comparable to results achieved on control plots of introduced agronomic species.
- The cost of native species seed is no more than minimally higher than the cost of agronomic seed.

METHODS

To date, we have undertaken the following activities to achieve our long-term objective:

- collect seed from selections of grasses, which are native to the relevant area(s);
- increase the available seed, using a selection/seed-increase nursery, to establish trial plots;
- establish replicated trial plots on disturbed sites (accompanied by control plots seeded to the optimal mixture of available introduced agronomic selections) to determine the utility of the selections collected for reclamation purposes;
- evaluate trial plots for ground-cover production on a species-by-species basis using the "Daubenmire" methodology;
- *t*-test the ground-cover percentages of native seed plots versus the agronomic seed control plots;
- test germination of the most successful selections; and
- establish breeders' seed production plots to ascertain the seed production potential of the native selections and subsequent cost of the seed to the end-user.

DISCUSSION

Vancouver Island Program

On Vancouver Island, Forest Renewal British Columbia is funding a long-term research program that, if successful, will result in the use of native grass species, and possibly some legumes, for forestry, and other, reseeding purposes. The native species in this program may also be applicable to the Coastal Western Hemlock biogeoclimatic zone on the mainland coast. In the last 4 years, 104 native selections have been collected. These were seeded to flats in a greenhouse at the University of British Columbia. The seedlings were then transferred to a seed-increase nursery established just south of Duncan. Many selections were eliminated because of poor germination or poor performance, but 60 selections are currently established at the nursery. Seed from these selections has been used to create five native grass-seed mixtures. Each mixture was seeded to replicated trial sites and unique demonstration sites on Vancouver Island. Although 45 trial sites were established throughout Vancouver Island, these have not yet provided definite conclusions. However, initial results at each replicated trial site indicate that native species furnish ground cover comparable to that of the agronomic cultivars on the control plots. In 1999, the 11 selections with the greatest initial success were seeded to breeders' seed production plots near Dawson Creek. Performance on these plots will provide a good indication of the eventual cost of the native selections when grown at field-scale.

Northwestern Canada Program

For northern reclamation purposes, M. Vaartnou and Associates are working with the Alberta Research Council and the Dawson Seed Company to ensure a reliable, reasonably priced source of native grass seed. Northern selections were tested from 1976 to 1995 at numerous locations throughout northern Alberta, northern British Columbia, and the Yukon Territory, as well as some locations in the Rocky Mountains and the Northwest Territories. These northern selections were seeded to field-scale production in the late 1970s, and again in the early 1990s; however, these programs have been terminated. We incorporated the results of these field trials into the Yukon Department of Renewable Resources' reclamation manual ("Guidelines for Reclamation/ Revegetation in the Yukon"). Results were also presented at conferences (e.g., the 1988 Conference for the 25th Anniversary of the Boreal Institute of the University of Alberta; the 1992 British Columbia Mine Reclamation Symposium at Smithers, B.C). In early 1998, the Alberta Research Council expressed an interest in working with our selections. Eight selections were subsequently sent to Alberta for possible development into registered northern agronomic cultivars. Initial results are promising, and it is probable that some agronomic cultivars will be registered by 2002–2004. In 1999, the Dawson Seed Company requested permission to grow our northern native species selections for seed production and marketing. These selections have been successful in northern field trials, and seed from this latter initiative could be on the market by 2002.

AUTHOR

* ***Correspondence to:*** **Manivalde (Many) Vaartnou**, M. Vaartnou & Associates, 11520 Kestrel Drive, Richmond, BC V7E 4E2.

E-mail: vai_vaartnou@bc.sympatico.ca

Tree encroachment in the south Okanagan and lower Similkameen valleys of British Columbia

JENNIFER TURNER* AND PAMELA KRANNITZ†

INTRODUCTION

Loss of grassland in the Cariboo-Chilcotin has been related to encroachment and ingrowth of Douglas-fir (*Pseudotsuga menziesii*) and lodgepole pine (*Pinus contorta*). Strang and Parminter (1980) found that a combination of fire suppression, lack of grass competition, and particular microsite conditions were the contributing factors to tree encroachment. The Cariboo-Chilcotin region has a moister, cooler climate than that of the south Okanagan and lower Similkameen valleys, where the average annual precipitation is only about 300 mm. It is unknown whether tree encroachment, in this case by ponderosa pine (*Pinus ponderosa*), is also a problem in these semi-desert grassland habitats of the southern Interior. Here, the conservation concern over tree encroachment is even more urgent because of the high biodiversity of the area, and the great number of species at risk.

This study shows that tree encroachment and ingrowth are occurring in the hottest and driest habitats of the south Okanagan and Similkameen valleys. We also show that fire reverses this trend, which supports efforts to reintroduce fire to these regions.

METHODS AND STUDY AREA

Fifty study sites in the Ponderosa Pine and Bunchgrass biogeoclimatic zones were chosen from aerial photographs taken in 1938, 1985, and 1996. A count of the total stems was taken for each site using a stereoscope. All conifers that could be distinguished on the photographs were counted, but deciduous trees were not included.

The 1985 and 1996 photographs were scanned into digital (raster) format and then geo-referenced using TRIM data of roads and water features (Albers projection). ERDAS Imagine® spatial analyst software was used to geo-reference the scanned photos. This was done to minimize distortion of the photographs for a more accurate spatial determination. Similar landscape features between years were selected and stored into the ERDAS program as ground control points. At least six control points were located for each of the photographs.

A paired *t*-test was conducted to determine whether a change in tree density occurred between 1938 and 1985, and 1985 and 1996. Tree density was standardized for site size before analysis with SAS (1990). Sites that experienced burns in the 1940s were considered "unburned" because of the intervening time to 1985. The *t*-tests were analyzed separately for burned and unburned sites. A three-way ANCOVA was used to determine the significance of different factors influencing tree ingrowth. The co-variable was site size;

CITATION —

Turner, J.S. and P.G. Krannitz. 2000. Tree encroachment in the south Okanagan and lower Similkameen valleys of British Columbia. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 81–3.

the three factors were biogeoclimatic zone, latitude (north versus south), and whether or not the site burned in the intervening period.

RESULTS AND DISCUSSION

Significant tree ingrowth was evident at unburned sites, both between 1938 and 1985 ($t = 6.84$, $p = 0.0001$, $df = 2, 40$), and between 1985 and 1996 ($t = 3.85$, $p = 0.0005$, $df = 2, 35$).

Not surprisingly, tree encroachment was higher between 1938 and 1985 than between 1985 and 1996, but the rate was not different (mean rates = 0.125 stems per hectare per year [± 0.175 SE, $n = 41$] and 0.122 stems per hectare per year [± 0.213], respectively; $t = 0.089$, $p > 0.5$, $df = 2, 77$). Sites that experienced fire showed decreases in tree density between 1938 and 1985 ($t = -3.04$, $p = 0.0005$, $df = 2, 8$). Only two sites burned between 1985 and 1996. At one, tree density decreased from 565 stems per hectare in 1985 to 311 stems per hectare in 1996. At the other, tree density decreased from 29 stems per hectare in 1985 to 22 stems per hectare in 1996.

Fire was the only factor influencing the amount of tree ingrowth between 1938 and 1985 ($F = 14.18$, $p = 0.0005$) and between 1985 and 1996 ($F = 6.62$, $p = 0.0149$). Through all years, more trees occurred in the north than in the south, and in the Ponderosa Pine zone than in the Bunchgrass zone. However, tree ingrowth was not less in the hotter biogeoclimatic zone, nor further south in the study.

Significant tree encroachment and ingrowth has occurred on unburned areas of the south Okanagan and lower Similkameen grasslands over the past 60 years. A study in the Chilcotin grasslands of British Columbia (Strang and Parminter 1980) also found that tree encroachment was a result of fire suppression, but it occurred in combination with other factors such as intensive livestock grazing and seedling establishment on favourable microsites.

The results of the ANCOVA show that no elevational difference was evident in tree encroachment and ingrowth. This is surprising, as one would expect more encroachment in the higher-elevation areas of the Ponderosa Pine biogeoclimatic zone, where environmental conditions are more suitable to seedling establishment and survival. However, Rummel (1951) found that heavy livestock grazing can be linked to higher levels of encroachment. Tisdale (1947) found that more intensive domestic livestock grazing occurs in lower valley regions because of their close proximity to human habitation. These areas also contain a higher proportion of grassland vegetation preferred by domestic livestock (Gayton 1996).

As would be expected, fewer trees were apparent in 1985 than in 1938 on burned sites. Fire suppression in the southern Interior of British Columbia can therefore be linked to tree encroachment into the grasslands of the south Okanagan and lower Similkameen valleys. Because of the importance of grassland habitats in the south Okanagan to biodiversity and endangered species, these results strongly support the need for the reintroduction of fire, or at least prescribed burns, in these semi-desert habitats.

REFERENCES

Gayton, D. 1996. Fire-maintained ecosystems and the effects of forest ingrowth. B.C. Ministry of Forests, Nelson, B.C. Bulletin.

Rummel, R.S. 1951. Some effects of livestock grazing on Ponderosa pine forest in central Washington. Ecology 32(4):594–607.

SAS Institute Inc. 1990. SAS procedures guide, version 6, 3rd edition. Cary, N.C.

Strang, R.M. and J.V. Parminter. 1980. Conifer encroachment on the Chilcotin grasslands of British Columbia. Forestry Chronicle pp. 13–18.

Tisdale, E.W. 1947. The grasslands of the southern interior of British Columbia. Ecology 28:346–65.

AUTHORS

* ***Correspondence to:*** **Jennifer S. Turner**, School of Natural Resources Conservation, Faculty of Forestry, University of British Columbia, 2424 Main Mall, Vancouver, BC V6T 1Z4.

E-mail: jenvernon@yahoo.com

† Canadian Wildlife Service, Pacific Wildlife Research Centre, Delta, B.C.

Range Reference Areas: Determining seral stages and vegetation change on permanent range in British Columbia

WAYNE ERICKSON*

INTRODUCTION

Range Reference Areas form a system of livestock exclosures with vegetation-response monitoring provided by the Ministry of Forests. These sites are established on grassland or forested range at the most advanced seral stage, usually the Potential Natural Community[1]. Sites protected from natural disturbances, such as fire, do not typify a potential natural community. For example, Natural Disturbance Type 4 in British Columbia consists of ecosystems in which frequent, low-intensity fires maintain grasslands, shrub lands, and open forests. Fire suppression has changed the character and structure of plant communities in this natural disturbance type.

Reference areas represent the diversity of provincial rangeland. The majority of reference areas are in the Kamloops and Cariboo regions, where permanent range[2] comprises a large percentage of the total land area.

Range Reference Areas are benchmark sites that provide an information base for range management decisions and ecological guidelines. These areas serve management by providing:

- measures of grazing impact and ecosystem response;
- indicators of forage production potential;
- potential natural communities and seral stages; and
- demonstration areas for range use and biodiversity issues.

MATERIALS AND METHODS

Range Reference Areas were selected with the aid of existing classification and knowledge of district range staff. To meet program objectives, it was necessary to exclude livestock, and, in some cases, wild ungulates. The minimum size for these fenced exclosures was set at 1 ha, but many were larger. They were sampled when established, and resampled at selected intervals to track changes over time. Measurements were also taken on adjacent grazed areas to allow comparisons. Vegetation monitoring took place on macroplots[3], and included:

- detailed site description (slope, aspect, soils, elevation, etc.);
- establishment of five permanent transects;
- estimates of foliar plant cover by species (50 Daubenmire plots or 500 intercept points), plus litter, bare ground, and cryptogams[4];

CITATION —

Erickson, W.R. 2000. Range Reference Areas: determining seral stages and vegetation change on permanent range in British Columbia. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 85–7.

- measurements of trees and shrubs along five intercept lines; and,
- photographs at three permanent photopoints.

RESULTS AND DISCUSSION

A team of five range staff (four in regions) instituted the program, which included several other participants. A network of 200 new Range Reference Areas was established, adding to the 161 existing ones. All of the exclosures built under this program have undergone detailed vegetation monitoring on permanent transects. Consistent measurements and the ability to detect change in foliar plant cover have been particular sampling concerns.

Continuously monitoring the exclosures, some of which date back to the 1920s, will provide crucial long-term information on the nature and extent of changes that have occurred on provincial rangelands. The process of extrapolating reference area results and setting desired plant communities has been initiated. A gap analysis has been completed to identify any shortfalls in the representation of provincial biogeoclimatic ecosystem units. In addition to Range Reference Area program monitoring, several sites are being used by universities and colleges for research.

Products to date for the program include:

- an atlas with a description of all current reference areas (planned for the Web site);
- a data management system ("Venus de Moo") (under development);
- plans to merge previously separate regional data systems;
- data entry for both new and historic data;
- exploratory analyses and a review of potential methods (initiated);
- a seral classification for deciduous woodlands in the Prince Rupert Forest Region; and
- a Web site (http://www.for.gov.bc.ca/hfp/range/rra/rra.htm).

The status of the program is now uncertain. It received major funding (by range standards) in the establishment phase from external sources (Co-ordinated Resource Inventory Initiative and Forest Renewal BC). Since this funding expires in March 2000, ways to continue the Range Reference Area program and protect this investment are being investigated. Full utility of the program will only be achieved if well-planned remeasurements are supported with data analyses and reporting of results.

Numerous benefits could be realized if this program is continued in the future. The Range Reference Area program could:

- create a scientific baseline and long-term inventory information on the nature and extent of changes occurring on provincial rangelands;
- permit assessment of whether recovery guidelines are achievable;
- aid in the description of desired plant communities required in Range Use Plans;
- inform land use and resource management decisions at the site level (through Range Use Plans) and the landscape level (through Higher-level Plans); and
- allow refinement of the provincial classification for permanent range ecosystem.

---

1 A Potential Natural Community is the plant community that would establish on an ecological site if all successional sequences were completed, without interference by humans, under the present environmental conditions. Natural disturbances such as drought, wild fires, grazing by native fauna, and insect defoliation are inherent in its development. This community may include acclimatized or naturalized non-native species. It is roughly equivalent to the concept of a climax. See also the Biodiversity Guidebook.

2 Permanent range provides substantial herbaceous forage throughout most or all natural successional sequences, and may include open conifer forest, aspen woodland, grasslands, shrub lands, wetlands, subalpine meadows and alpine.

3 A macroplot is a sampling unit. See Habitat Monitoring Committee (1990).

4 Cryptogams are ground layer mosses, lichens, and related life forms that form a soil crust.

REFERENCES

British Columbia Ministry of Forests. n.d. Range Reference Areas atlas. Range Section, Forest Practices Branch, B.C. Ministry of Forests, Victoria, B.C.

_____. n.d. Range Reference Areas strategic plan. Range Section, Forest Practices Branch, B.C. Ministry of Forests, Victoria, B.C.

_____. 1998. Range monitoring and assessment. Chapter 12. *In* Range manual. B.C. Ministry of Forests, Forest Practices Branch, Victoria, B.C.

British Columbia Ministry of Forests and B.C. Ministry of Environment, Lands and Parks. 1995. Biodiversity guidebook. Forest Practices Code, Victoria, B.C.

British Columbia Ministry of Forests and B.C. Ministry of Environment, Lands and Parks. 1995. Range management guidebook. Forest Practices Code, Victoria, B.C.

Floyd, D.A. and J.E. Anderson. 1987. A comparison of three methods for estimating plant cover. Journal of Ecology 75:221–8.

Habitat Monitoring Committee. 1990. Procedures for environmental monitoring in range and wildlife habitat management. B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks, Victoria, B.C.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, Toronto, Ont.

Whitman, W.C. and E.I. Siggeirsson. 1954. Comparison of line interception and point contact methods in the analysis of mixed grass range vegetation. Ecology 35:431–6.

AUTHOR

* ***Correspondence to:*** **Wayne R. Erickson**, Range Section, Forest Practices Branch, B.C. Ministry of Forests, PO Box 9513 Stn Prov Govt, Victoria, BC V8W 3E9.

E-mail: Wayne.Erickson@gems3.gov.bc.ca

Effects of grazing on soil compaction and water infiltration in forest plantations in the Interior of British Columbia

KLAAS BROERSMA[*], MAJA KRZIC[†], REG NEWMAN[‡], AND ARTHUR BOMKE[†]

INTRODUCTION

Grazing cattle on forest plantations in the Interior of British Columbia is a common practice. Soil compaction can occur following cattle use, although this may vary with stocking rate, vegetation type and age, soil type, soil water content, and climate. Several studies have shown that increased soil compaction can have a negative effect on the growth of young tree seedlings and on productivity in older plantations. These negative effects result from restricted root development, reduced water and nutrient availability, and reduced soil aeration.

This study evaluated the effects of cattle grazing and domestic forage seeding on soil bulk density and soil penetration resistance in lodgepole pine plantations in the Montane Spruce very dry cool biogeoclimatic subzone. The study was replicated on three sites near Kamloops, B.C.

MATERIALS AND METHODS

The two Tunkwa Lake sites were harvested in November 1986 and were windrowed, burned, and drag-scarified during November 1987. The majority of the Helmer Lake site was harvested in 1985, with an additional 10 ha harvested in October 1987. The Helmer Lake site was rough-piled and track-and-blade-scarified, and the piles were burned after the first snowfall.

All sites were aerially seeded in May 1988 to a forage seed mix of 35% orchardgrass (*Dactylis glomerata* L.), 5% timothy (*Phleum pratense* L.), 40% alsike clover (*Trifolium hybridum* L.), and 20% white clover (*Trifolium repens* L.) by weight. Seed was applied at a rate of 12 kg per hectare and equal areas were left unseeded. One-year-old, container-grown lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm. ex S. Wats.) seedlings were then planted at a density of 1400 stems per hectare. The sites were fenced into 5-ha pastures.

Grazing was initiated in 1989, the year following planting, and has continued for 8 years. Grazing was applied at 50% forage use, and a 0.5-ha exclosure was maintained as a control. The grazing period was kept constant at about 30 days. Cattle numbers were modified, depending on forage availability in each year, to achieve 50% use of forage.

The soils are generally Melanic Brunisols, with Luvisols occurring in mesic areas. The soil attributes at the sites suggest a moderate to high hazard rating for soil compaction and puddling (B.C. Ministry of

CITATION —

Broersma, K., M. Krzic, R.F. Newman, and A.A. Bomke. 2000. Effects of grazing on soil compaction and water infiltration in forest plantations in the Interior of British Columbia. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 89–92.

Forests and B.C. Ministry of Environment, Lands and Parks 1995). Soil bulk density and soil penetration resistance were determined in 1996 and 1997, both before and after the 1-month grazing period. Water infiltration rates were measured in 1997 after the 1-month grazing period.

RESULTS AND DISCUSSION

Soil Bulk Density

One month of grazing at an average cattle stocking rate of 0.69 AUM/ha was not sufficient to produce significant changes in soil bulk density. However, pastures grazed for 8 years (1 month each year since 1989) had higher soil bulk density than ungrazed exclosures (Figure 1). Eight years of cattle grazing has slightly increased soil bulk density by 6% relative to the ungrazed exclosures.

Pastures seeded to domestic forage species had greater soil bulk density than unseeded pastures (Figure 1). This was due to the higher number of cattle used to achieve 50% use of total forage on the seeded compared with the unseeded pastures. Seeded pastures supported greater numbers of cattle because of the increased forage production.

The soil bulk densities obtained in the grazed pastures during this study were well below the root-limiting critical range reported in other studies.

Soil Penetration Resistance

Eight years of grazing clearly increased soil penetration resistance relative to the ungrazed exclosure throughout most of the soil profile (Figure 2). Soil penetration resistance was always lower in the ungrazed control. In general, soil penetration resistance readings in the grazed pastures at most depths were not above the levels reported as thresholds of root-restricting conditions.

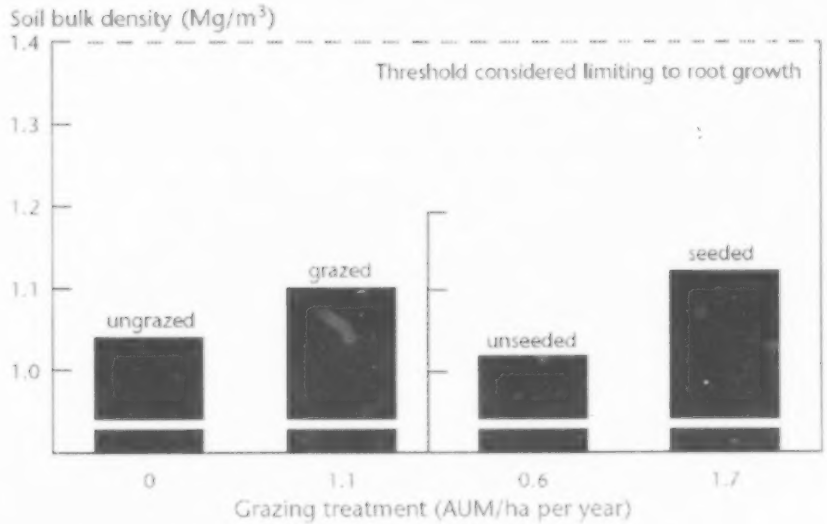

FIGURE 1 *Soil bulk density following cattle grazing for 8 years.*

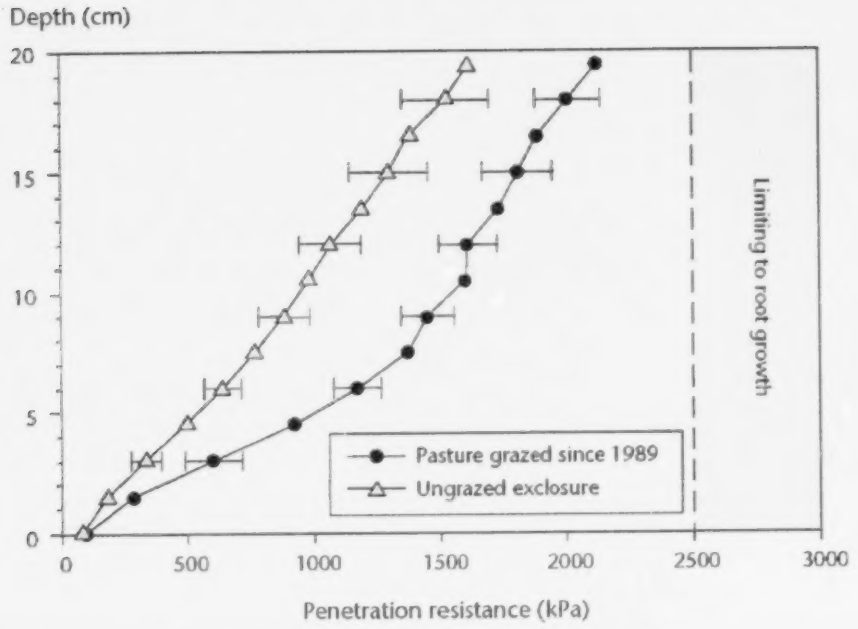

FIGURE 2 *Soil penetration resistance on seeded pastures grazed at 1.7 AUM/ha per year for 8 years.*

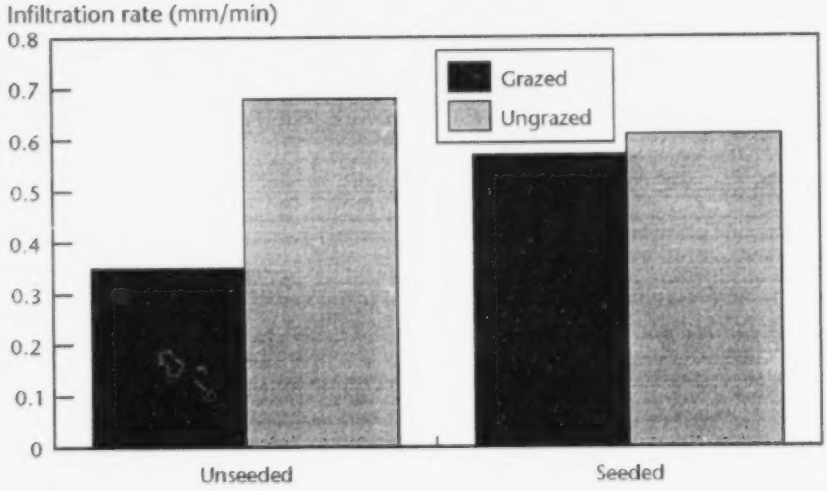

FIGURE 3 *Rate of water infiltration following long-term grazing and seeding to domestic forage species.*

Water Infiltration

Long-term grazing and forage seeding did not affect the rate of water infiltration (Figure 3).

SUMMARY AND CONCLUSIONS

Eight years of cattle grazing increased bulk density by 6% relative to the ungrazed exclosures. Similarly, soil penetration resistance is also higher on pastures grazed since 1989 than on ungrazed exclosures. This effect was consistent when measured both before and after the 1-month grazing period and throughout the top portion of the soil profile.

Although it was expected that seeding domestic forages would have an ameliorating effect on soil compaction, this was observed only in ungrazed exclosures. The higher number of cattle used to achieve 50% use of total forage on seeded compared to unseeded pastures resulted in greater soil bulk density.

Bulk density and penetration resistance data obtained in this study were well below the critical ranges considered as limiting to root growth (1.4 Mg/m^3 and 2500 kPa, respectively). It is unlikely that long-term cattle grazing at stocking rates from 0.6 to 1.7 AUM/ha per year will lead to root-limiting levels in soil compaction on forest plantations with moderate to high soil compaction hazard ratings.

ACKNOWLEDGEMENTS

Support for this project has been provided by Ainsworth Lumber (1987) Ltd., Savona, B.C.; Aspen Planers Ltd., Merritt, B.C.; Indian Gardens Ranch Ltd., Savona, B.C.; Gardens Creek Ranch Ltd., Savona, B.C.; and Guichon Cattle Co. Ltd., Quilchena, B.C. Financial assistance for this project was provided by Forest Renewal B.C.

REFERENCES

British Columbia Ministry of Forests and B.C. Ministry of Environment, Lands and Parks. 1995. Hazard assessment keys for evaluating site sensitivity to soil degrading processes guidebook. Forest Practices Code. Victoria, B.C.

AUTHORS

* ***Correspondence to:*** **Klaas Broersma**, Agriculture and Agri-Food Canada, 3015 Ord Road, Kamloops, BC V2B 8A9.

E-mail: broersmak@em.agr.ca

† University of British Columbia

‡ B.C. Ministry of Forests, Research Branch

Cut-to-length partial-cutting trial in the Okanagan

ERIC PHILLIPS*

INTRODUCTION

Partial cutting is required in areas where forest cover must be maintained to meet silvicultural objectives or to support non-timber values. The Okanagan has an arid climate and water quality is often a concern, requiring cut-and-leave patterns to meet hydrological considerations. Large areas of mature pine are harvested in sections (two or more passes) to meet cutblock size and green-up requirements. Second-pass lodgepole pine stands are often overmature, and are subject to stand disintegration through insect and disease attack, thereby reducing the timber volume available for utilization. This study looks at the economics and site effects of partially cutting stands with a cut-to-length (short-wood) system.

Harvester/forwarder harvesting systems are costly to purchase and maintain, but have potential to increase operator safety, eliminate roadside debris piles, and minimize site disturbance. The goal of this study was to identify some of the limitations of the equipment.

The objectives of the study were to:

- investigate several applications for mechanized short-wood systems in partial cutting applications;
- determine the overall productivity of the harvesting/forwarding system on a variety of sites, and calculate phase costs;
- obtain detailed information on the harvesting phase of the operation and the effect of critical site conditions on productivity;
- report on the operational factors associated with the harvesting, including post-harvest soil surface condition, residual tree damage, and slash loading; and
- establish plots to describe development of vegetation following harvest.

MATERIALS AND METHODS

Cut-to-length harvesting with a Timberjack harvester and forwarder was studied on nine harvesting blocks in the Okanagan region of British Columbia from 1996 to 1999 with funding from Forest Renewal BC. The study blocks included patch cuts, partial cuts, and clearcuts, which were prescribed to salvage tree mortality resulting from insect attack and windthrow.

The operational logistics, cost, and productivity of harvesting were studied on a shift basis using a machine activity recorder and daily logbooks, and on a cycle-by-cycle basis (detailed timing) using stopwatches and hand-held data recorders. The cost per hour ($ per scheduled machine hour) was calculated using the Forest Engineering Research Institute of Canada's (FERIC) costing model. Volumes were determined from log counts and roadside scaling.

A rectangular grid was established in each treatment. At each grid intersection point, a circular plot

Citation —

Phillips, E.J. 2000. Cut-to-length partial-cutting trial in the Okanagan. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 93–5.

was established to assess vegetation by layer and to measure residual tree characteristics, including damage measured by depth class and size (Mitchell 1994). Slash loading was measured by diameter and decay class using the line-intersect method (Sutherland 1986; Hopwood 1991) along two transects radiating from each grid point. Soil surface condition was point-sampled along the slash lines (Curran and Thompson 1991). Changes in whole-soil (total soil) bulk density were measured in place on the major forwarding trails using a single-probe nuclear densiometer with paired disturbed/undisturbed sampling.

RESULTS AND DISCUSSION

The cut-to-length system was used successfully to harvest portions of stands and windthrow, meeting numerous silvicultural objectives. The nine blocks had a variety of terrain and operational limiting factors. These included swampy areas, irregular block boundaries, steep favourable and adverse slopes, deep snow, complete and partial windthrown stands, and feathered edges. The system adapted to each of these constraints, but cost to roadside was 11–78% higher than the cost of clearcutting under favourable conditions (Table 1).

Patchcutting alone did not appear to affect the harvester's productivity, but did affect that of the forwarder, which resulted in an 11% overall cost increase. Deep snowpack affected both harvester and forwarder productivity, as did slope. Average tree size was the single factor that most affected harvester productivity. However, the highest cost was recorded when the harvester was not operating at peak mechanical efficiency. The cost of salvaging windthrown trees, with their lack of uniform orientation, added about 20% to the base cost. Steep slopes alone increased costs another 20%.

Soil surface effects were confined primarily to forwarding trails, and represented 11–27% of the area sampled. The significance of these effects varied depending on the sensitivity of the soils to compaction. The lowest levels of disturbance were recorded in the patch and partial cutblocks.

The greatest amount of residual tree damage was recorded in the windthrow partial cutblock, where approximately five times as many trees did not meet the Forest Practices Code (FPC) "short-term

TABLE 1 *Cost and site limitation comparison*

Treatment	% Increase from base cost	Site limitations
Clearcut 1	0	Gentle terrain; good access; well-drained soil
Patch cut 1	11	Gentle terrain with a small wet area
Partial cut 1	38	Gentle terrain, irregularly shaped block fragmented by swamp
Clearcut 2	38	Steep favourable slopes, some adverse, some wet areas; small non-merchantable material
Partial cut 3	41	Steep favourable slopes, wet patches; windthrow salvage
Partial cut 2	48	Steep favourable slope with benches
Partial cut 4	58	Gentle slopes; deep snow
Patch cut 3	64	Gentle slope, but steep drop on margin; feathered edge; large non-merchantable material
Patch cut 2	78	Gentle adverse slope; mechanical problems slowed harvesting; irregular block boundary

retention" requirements compared to the two partial cutblocks harvested. Harvesting when the sap was running in the spring increased the number of trees not meeting FPC short-term retention requirements by two to three times.

Slash loading varied between treatments, but was highest in the windthrow salvage.

Longer-term vegetation plots will determine the influence of the treatments on the remaining stand and vegetation succession. In all blocks, the cut-to-length harvesting method met the silvicultural objectives without compromising worker safety.

Complete results will be summarized in a forthcoming FERIC technical report.

REFERENCES

British Columbia Ministry of Forests and B.C. Ministry of Environment, Lands and Parks. 1997. Tree wounding and decay guidebook. Forest Practices Code. Victoria, B.C.

Curran, M. and S. Thompson. 1991. Measuring soil disturbance following timber harvesting. B.C. Ministry of Forests, Victoria, B.C. Field Guide Insert No. 5.

Hopwood, D. 1991. Principles and practices of new forestry. B.C. Ministry of Forests, Research Branch, Victoria, B.C. Land Management Report No. 71.

Mitchell, J.L. 1994. Commercial thinning of mature lodgepole pine to reduce susceptibility to mountain pine beetle. Forest Engineering Research Institute of Canada, Vancouver, B.C. Special Report SR-94.

Sutherland, B.J. 1986. Standard assessment procedures for evaluating silvicultural equipment: a handbook. Canadian Forest Service, Sault Ste. Marie, Ont.

AUTHOR

* ***Correspondence to:*** Eric J. Phillips, Senior Researcher, Silvicultural Operations, Forest Engineering Research Institute of Canada (FERIC), 2601 East Mall, Vancouver, BC V6T 1Z4.

E-mail: eric-p@vcr.feric.ca

Alternative silvicultural systems: Harvesting logistics and costs

JANET MITCHELL*

INTRODUCTION

Partial cutting is required in areas where forest cover must be maintained to meet silvicultural objectives or to support non-timber resources such as wildlife habitat or visual quality. The Forest Engineering Research Institute of Canada (FERIC) has conducted several studies to document harvesting techniques that can meet non-timber resource requirements, as well as maintain acceptable harvesting costs and minimal effects on the site, stand, and wildlife habitat. Here we focus on three FERIC studies that examine the effects of opening size, orientation, and retention level on regeneration, visual quality, and mule deer winter range. The emphasis is on the respective productivity and relative costs of the different phases of the harvesting operations and operating constraints.

In the first study (Horsefly Lake), the B.C. Ministry of Forests, in co-operation with the Williams Lake Division of Weldwood of Canada Limited and the B.C. Ministry of Environment (Williams Lake), examined the effects of harvesting trees from small openings on mule deer winter habitat in an area with high recreation values. In the second study (Sicamous Creek), the B.C. Ministry of Forests (Kamloops Forest Region), in co-operation with the Lumby Division of Riverside Forest Products Limited, explored the effects of five canopy opening sizes on regeneration of a high-elevation forest near Sicamous, B.C. In the third study (Cornish Mountain), the Quesnel Division of West Fraser Mills Ltd. investigated the effects of opening size, orientation, and retention level on visual quality in the Barkerville corridor near Quesnel, B.C. FERIC monitored the harvesting phase in all the studies.

Overall objectives in the three studies were to:

- determine the economic feasibility of harvesting timber from small openings;
- determine the productivity and costs of harvesting;
- evaluate the equipment and operating practices used during the harvesting phase; and
- identify operating constraints.

MATERIALS AND METHODS

To obtain shift-level information, FERIC installed Servis recorders on all harvesting machines and maintained daily crew records. To supplement the shift-level data, specific information on the falling, skidding, and processing cycles was obtained by detailed timing. Harvested wood volumes were obtained

Citation —

Mitchell, J.L. 2000. Alternative silvicultural systems: harvesting logistics and costs. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 97–100.

from the Licensee's weigh-scale receipts. Costs were calculated using FERIC's standard costing method, and were not those experienced by the contractor; these costs did not include supervision, overhead, profit, and risk allowances.

Study One (Horsefly Lake)

The study block was divided into four treatments based on canopy opening size: four 0.25-ha openings, four 0.50-ha openings, ten 1.0-ha openings, and two 2.0-ha openings, for a total of 20 openings (Waterhouse 1998). Approximately 20% of the total study block was harvested including roads, landings, and openings. Openings were located across and along topographical contours to provide varying amounts and intensities of light, and to cover the range of ecosystem associations and levels of frost drainage. After mechanical harvesting (feller-buncher and grapple skidder), eleven openings were site prepared and eight openings were left without site preparation. The remaining opening had root rot (*Armillaria ostoyae)* infections; one-half was stumped and the other half treated with a biological control fungus. Planting was done the following spring.

Study Two (Sicamous Creek)

The Sicamous Creek study area was divided into five treatment units based on canopy opening size: an untreated control, single-tree selection, 0.1-ha group selection, 1.0-ha patch cut, and 10-ha clearcut (Mitchell 1996). The treatments were replicated three times, for a total of 15 units. In all treatment units, except two of the single-tree selection units, mechanical harvesting systems (feller-bunchers and grapple skidders) were used. In the two remaining single-tree selection units, a conventional harvesting system (manual falling and line skidding) was used. After treatment, the units were subdivided to accommodate two treatments—mounding with an excavator and no site preparation. Planting followed.

Study Three (Cornish Mountain)

The study block was divided into 13 openings ranging in size from 2.0 to 9.8 ha. Only six openings (5 clearcuts and one with group selection for one-half of the opening and clearcut for the other half) were completed during the 1998 winter season and therefore only those were included in the study. The two contractors used a conventional harvesting system (manual falling and line skidding). In the group selection, the faller was guided by West Fraser Mills Ltd. in how many trees to fell, based on visual assessment from the main highway to Barkerville.

RESULTS AND DISCUSSION

Developing a block for partial cutting requires a long-term vision of the forest stand. Planning the location, shape, and orientation of the openings must consider multiple entries. Planning must also include the access roads, landings, and the skid trails or corridors within the openings and between them. The trail pattern must allow skidding without damage to residual trees, while maintaining acceptable levels of productivity. The layout and marking of boundaries for small openings require more time per cubic metre of wood harvested than for larger openings.

The significance of any cost increases will depend on the effect of the opening sizes and post-harvest treatments on regeneration performance and non-timber resources. The degree of success of the projects will not be known until the research components carried out by the other agencies are completed. The final decision on success or failure of harvesting by small openings can only be determined in the long term, after the future entries are completed.

Study One (Horsefly Lake)

The treatment with the highest falling productivity was the 2.0-ha openings at 108 m^3/productive machine hour (PMH) followed by the 0.25-ha openings at 107 m^3/PMH, the 1.0-ha openings at 97 m^3/PMH, and the 0.50-ha opening at 80 m^3/PMH. Skidding productivity, standardized to 200 m, was higher for the 2.0- and 1.0-ha openings (33 and 32 m^3/PMH, respectively) than the 0.25- and 0.50-ha openings (at 27 and 25 m^3/PMH, respectively).

There was a 2% increase in the cost of harvesting the 1.0-ha openings over the 2.0-ha openings, while the costs of harvesting 0.25- and 0.50-ha openings increased by 9 and 20%, respectively.

In this study, opening size had a minimal effect on harvesting productivity and costs. Harvesting of the block by small openings was feasible with some increase in cost (up to 20%) which could be reduced at the planning stage by adding another landing to shorten the skidding distances.

Study Two (Sicamous Creek)

Layout costs for the 0.1-ha group selection and 1.0-ha patch cut treatment units were almost double that of a conventional clearcut block because the smaller units had a greater length of boundary to mark than 10.0-ha clearcuts. Marking of the residual trees may be useful for training purposes, but is unnecessary with well-trained operators.

Harvesting productivity ranged from 2.1 to 9.6 m^3/ha and costs ranged from \$11.07 to \$30.66/m^3. Harvesting productivity and cost were affected more by the machine complement of the harvesting system, the harvesting procedure, and the harvested volume than by the treatment. Mechanical harvesting systems were more productive than conventional systems and the 10-ha opening had the highest productivity of the mechanical systems. The feller-buncher operator was able to maintain a high productivity in the single-tree selections units and placed the stems accurately for the skidding phase. This is only possible with an experienced operator who is committed to the operation.

Study Three (Cornish Mountain)

Block size, weather conditions, and operating procedure influenced falling productivity. The largest block had the highest falling productivity and the smallest block had the lowest (28.2 and 14.9 m^3/ha, respectively). The cold weather negatively affected the falling productivity. The faller who divided his time between falling and bucking had the higher productivity.

Block layout, distance, slope, and operating procedure affected skidding productivity.

Overall harvesting costs were affected more by skidding productivity than falling productivity. Openings with few landings, or that were irregularly shaped, required longer skid trails and had lower productivity. This should be accounted for in the planning and layout stages of block development. The increase in skidding cost may be acceptable if a block has fewer roads and landings, and visual impact is minimized.

West Fraser Mills had good communication with both contractors and members of the local community throughout the project. This communication, combined with the experience of the crews and their willingness to try new things, resulted in the treatment objectives being met.

REFERENCES

Mitchell, J.L. 1996. Trial of alternative silvicultural systems in southern British Columbia: summary of harvesting operations. Forest Engineering Research Institute of Canada, Vancouver, B.C. Technical Note TN-240.

Waterhouse, M.J. 1998. Silvicultural systems for Douglas-fir stands on very deep snowfall mule deer winter ranges. Cariboo Forest Region, B.C. Ministry of Forests, Williams Lake, B.C. Extension Note 23.

AUTHOR

* ***Correspondence to:*** **Janet L. Mitchell**, Forest Engineering Research Institute of Canada, Western Division, 2601 East Mall, Vancouver, BC V6T 1Z4.

E-mail: janet-m@vcr.feric.ca

Testing forest vegetation management options in British Columbia

BALVINDER BIRING* AND PHILIP COMEAU†

INTRODUCTION

The mission of the forest vegetation management program is to ensure successful establishment and maintenance of many reforested areas to a free-growing stage while protecting other public forest resources in British Columbia. During 1996/97, approximately 72 529 ha of Crown forest land received brushing treatments to ensure establishment and growth of young seedlings at a cost of $34.3 million. It is estimated that 80 000 ha of Crown forest land must be brushed annually in the province. Also, the demand for long-term information about issues, such as free-growing, green-up, growth and yield, biodiversity, stand dynamics, and stand structure, has increased substantially because of recent changes in provincial forestry legislation. Thus, ongoing testing and demonstration of promising vegetation management treatment options is needed to improve the development of cost-effective, environmentally sound, and socially acceptable vegetation management prescriptions.

Several experiment projects (EP) are under way to test promising integrated forest vegetation management options that focus on unique vegetation management objectives. We discuss five of these projects here.

EP 1135.01: Effectiveness of single and repeated manual cutting, and glyphosate for release of Engelmann spruce from a mixed shrub community in the ICHvk subzone

In 1991, a research trial consisting of eight treatments (see Table 1, page 21) was established at Soards Creek, near Mica, B.C. Treatments were replicated three times and assigned randomly to 30 × 30-m plots. Hand tools (e.g., grass whips, hand shears, machetes) were used to cut the vegetation to ground level. Glyphosate (2.1 kg ai/ha) was applied with a backpack sprayer. Within each treatment plot, 20 spruce seedlings were measured during the fall of each year. From 1992 to 1996, vegetation was assessed during the summer within 1.26 m radius plots centred on each of 10 crop seedlings in each treatment plot.

Results Repeated cutting for 3 years and glyphosate application resulted in reductions in total vegetation cover for 3 years. However, because of regrowth, no significant differences in total cover were detected among treatments. Treatments had a significant effect on vegetation height from 1993 to 1995.

Spruce survival 5 years after the treatments was high (> 85%) in both treated and untreated control plots (see Table 1, page 21). Glyphosate application and repeated cutting (annually or twice a year) resulted in spruce seedlings with significantly larger root collar diameter than untreated seedlings at the end of 5 years. Repeated summer cutting significantly increased fifth-year height over that of untreated seedlings and seedlings which only received a single summer manual treatment.

CITATION —

Biring, B.S. and P.G. Comeau. 2000. Testing forest vegetation management options in British Columbia. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 101–3.

EP 1135.03: A comparison of mulch mat and herbicide treatments for reducing grass competition in the IDFww subzone

In 1993, a research trial consisting of five treatments (Table 1) was established in the Nahatlatch River drainage north of Boston Bar, B.C. Treatments were replicated four times and randomly assigned to 15 × 15-m plots. Herbicide treatments were applied before planting using a R+D backpack sprayer with a 4-m boom. Tredegar® mulch mats were installed with five metal staples.

Results Treatment with glyphosate and hexazinone effectively controlled the grass community for three growing seasons (Table 1). The percent cover of herbs and shrubs (e.g., *Mahonia aquifolium*) was reduced for only one growing season after herbicide treatment. The mat treatments significantly reduced herb cover for three growing seasons. In 1997, Douglas-fir diameter and height were significantly larger in both herbicide treatments (glyphosate and hexazinone) compared to the untreated control (Table 1). The seedling survival was also significantly better in both herbicide treatments compared to the untreated control.

TABLE 1 *Means of fifth year (1997) Douglas-fir seedlings and fourth-year (1996) vegetation data*

Treatment	RCD[a] (mm)	Height (cm)	Survival (%)	Grasses % cover	Herbs % cover	Shrubs % cover
Untreated control	7.4b	41.7b	57.5b	11.6a	35.9a	18.1
Glyphosate (2.1 kg ai/ha)	12.7a	62.8a	95.0a	4.3b	25.8ab	14.4
Glyphosate (1.0 kg ai/ha)	10.4ab	53.7a	92.5a	6.0ab	32.2ab	17.3
Hexazinone (2.1 kg ai/ha)	14.6a	69.1a	80.0a	4.5b	22.7ab	13.0
Tredegar® mats (90 × 90 cm)	9.9ab	55.7a	72.5ab	7.3ab	16.2b	9.6

a RCD = root collar diameter.

EP 1135.05: Biological control of aspen and Sitka alder using the mycoherbicide *Chondrostereum purpureum* in the ICHmk and MSdm subzones

A research trial consisting of nine treatments (Table 2) was established in 1995 at two study sites to control aspen in ICHmk and Sitka alder in MSdm subzones. Treatments were replicated five times using a

TABLE 2 *Treatments means for total aspen stems 3 years after treatment*

	Treatment	Total aspen stems per hectare
BB	BC formulation × BC C.p. isolate (2139)	15 701
OB	Ontario formulation × BC C.p. isolate (2139)	24 669
BO	BC formulation × Ont. C.p. isolate (Jam6)	27 855
OO	Ont. Formulation × Ont. C.p. isolate (Jam6)	25 493
O	Ontario blank formulation	19 721
B	BC blank formulation	18 566
R	Release, herbicide (30% solution with mineral oil)	18 604
C	Brushed only (cut stump)	24 939
U	Untreated control (not brushed)	13 874

randomized complete block design. All treatment plots (except uncut control) were manually brushed before the cut-stump application of treatments.

Results Three years after treatment total aspen stems, stem height, diameter, basal area, and stem volume were not significantly different between treatments (Table 2).

EP 1192: Experimental design Protocol for Long-term Operational Response Evaluations (EXPLORE)

This protocol provides a standard methodology for the establishment of operational experiments in silviculturally treated areas. It provides information on the effects of silvicultural practices on forest regeneration, stand dynamics, stand structure, community diversity, free-growing, green-up, and growth and yield. (See Working Paper 31, available online at: http://www.for.gov.bc.ca/hfd/pubs/Docs/Wp/Wp31.htm)

EP 1195: Remeasurement of vegetation management research trials 5+ years after treatment

Table 3 provides a list of trials established throughout the province to provide the long-term conifer and vegetation response data required to assess the effects of brushing activities on timber and non-timber resources.

TABLE 3 *EP 1195 remeasurement sites*

Site name/BEC zone	Treatments	Reference
Sunset Prairie site prep./ BWBS	Disked and undisked, with/without glyphosate	Working Paper No. 43
Mackay River herbicide/ ESSF	Control, manual cutting, 2,4-D amine; 2,4-D ester, glyphosate	Research Report No. 11
Redfish Creek manual brushing/ICH	Control, manual cuttings (1–3 times)	Extension Note No. 20
Bush River/ ICH	Control, manual cutting, 2,4-D amine, glyphosate	Information Report BC-X-379
Operational herbicide trials/SBS	Control/glyphosate	Extension Note (in prog.)

AUTHORS

* ***Correspondence to:*** **Balvinder S. Biring**, B.C. Ministry of Forests, Research Branch, P.O. Box 9519, Stn Prov Govt, Victoria, BC V8W 9C2.

E-mail: Balvinder.Biring@gems3.gov.bc.ca

† B.C. Ministry of Forests, Research Branch

Partial cutting in root disease infected stands in the Interior Cedar–Hemlock biogeoclimatic zone

DEB DELONG*, PHILIP COMEAU†, AND CINDY PRESCOTT‡

INTRODUCTION

In the summer of 1993, the Nelson Forest Region's Forest Sciences section initiated an interdisciplinary research project (EP 1186) to test the use of partial cutting and root disease treatments in root disease infected stands in two Interior Cedar–Hemlock (ICHmw2 and ICHmk1) subzones. This study is being conducted on two sites:

- Mount Seven near Golden, B.C., which is infected with Tomentosus root disease; and
- Ice Road near Burton, B.C., which is heavily infected with Armillaria root disease.

Conventional or pushover harvesting techniques were implemented in 1-ha treatment units prescribed as clearcuts, light-retention shelterwoods, or heavy-retention shelterwoods. Logging was completed at the Mount Seven site during the winter of 1994/95; treatment units were planted in the spring of 1995. Establishment and first, second, and third growing season measurements are now complete. The Ice Road site was logged during the winter of 1995/96; therefore, activities at the site occur one year behind those at Mount Seven.

This summary outlines initial findings of the understorey light evaluation completed over the summer of 1997, preliminary results of the decomposition component, and preliminary results of the regeneration component after three growing seasons. For more detail about study objectives, project design, harvesting operations, and post-harvest assessments, see DeLong (1995) and Nelson Forest Region (1996).

UNDERSTOREY LIGHT

Fisheye photographs were taken at selected locations at the Ice Road site to characterize light conditions following harvesting (understorey light at the Mount Seven site was not studied). Locations included one clearcut, two light shelterwood, two heavy shelterwood, and two control treatment units. A program called GLI-C was used to analyze the images and estimate growing season light conditions at a height of 1 m above forest floor. This program provides estimates of the global light index (GLI), which is a measure of total growing season light (i.e., direct and diffuse) for each treatment type.

Results show that, as expected, light levels increase as a stand becomes more open. However, total stand basal area was not a great predictor of understorey light levels because of the variation in crown

Citation —

DeLong, D. 2000. Partial cutting in root disease infected stands in the Interior Cedar–Hemlock biogeoclimatic zone. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 105–12.

TABLE 1 *Understorey light levels at Ice Road site*

Treatment	BA (m^2/ha)[a]	Open (%)[b]	GLI (%)[c]
Control	110.3	11.0	14.96
Control	103.8	13.08	21.95
Shelterwood; heavy conventional	91.5	32.15	43.24
Shelterwood; heavy pushover	98.1	37.67	53.21
Shelterwood; light conventional	53.2	44.81	59.34
Shelterwood; light pushover	62.3	48.34	63.71
Clearcut	0	71.82	92.04

a BA = residual basal area (all species).
b Open = percent of sky visible through canopy openings.
c GLI = percent of total (direct plus diffuse) radiation that penetrates through the canopy (relative to open sky).

shapes, sizes, and densities in mixed species stands (Table 1). Results suggest it is better to use the basal area of each species as separate, independent variables when estimating light levels.

Light levels in the control units were lower than those required for growth of most conifer species. However, post-harvest light levels in all the treated units, including heavy-retention shelterwoods, were acceptable for conifer growth.

Additional photographs will be taken at other locations at the Ice Road site. Quantum sensors will be installed to provide data for local calibration of results (i.e., to calibrate estimates from fisheye photographs with actual measured light levels).

DECOMPOSITION

The rate of decomposition of several types of litter is under study at both the Mount Seven and Ice Road sites to determine the effects of various silvicultural systems and harvest methods on decomposition. Mesh bags containing pre-weighed amounts of various types of litter were placed on the ground in a number of treatment units, and left for 1–2 years before collecting and reweighing.

Results from the Mount Seven site show no significant differences between the treatments after 1 year of decomposition. After 2 years, significant differences were evident in the mass of Douglas-fir needle litter remaining compared to the other four litter types under study (aspen leaf litter, forest floor litter, lodgepole pine needle litter, and green spruce needles).

Litter loss from mesh bags in control units (unharvested) at Mount Seven was less than losses from most of the harvested plots. Litter may decompose faster on pushover plots (where bags were located on mineral soil) than on conventionally harvested plots (where bags were located on forest floor); however, no significant differences were evident.

At the Ice Road site, three different types of litter were studied: lodgepole pine needles, western larch leaves, and aspen leaves. Unlike the Mount Seven results, mass loss after 1 year tended to be greatest in the control units and least in the clearcuts. However, this difference was only significant for the pine needle litter. No consistent trend was evident in differences between pushover and conventionally harvested plots at the Ice Road site, and no significant differences existed between these treatments.

In an additional analysis combining both sites, significant differences were evident between the two sites, but no overall treatment differences were noted. The study in ongoing.

REGENERATION

The regeneration component of EP 1186 assesses survival and growth of planted, advanced, and natural regeneration (i.e., germinants). The following information summarizes third growing season results from the two study locations.

Mount Seven: Planted Seedlings

Survival Douglas-fir, larch, and spruce seedlings were planted in sample plots at the Mount Seven site. Average mortality of planted seedlings after three growing seasons was 13% (see Figure 1). The annual mortality rate was lower in 1997 than 1996 and remaining seedlings generally show good vigour.

Results showed little difference in total mortality between treatments and no apparent trends; however, spruce had significantly lower mortality than either larch or fir. Larch and fir both showed moderate mortality regardless of treatment (though larch mortality increased slightly with increasing overstorey), which may indicate poor planting stock, or, in the case of larch, poor site suitability.

Vigour Surviving seedlings generally have good vigour and the data showed no trend in seedling vigour between treatments. Douglas-fir seedlings were not quite as vigorous as larch and spruce; however, they averaged more than 70% in good condition.

Damage None of the seedling damage observed to date is considered serious, and seedlings will likely outgrow most of it (i.e., forked stems and chlorotic foliage). The most common type of damage—forked leaders—occurred in all species, but was most frequent in Douglas-fir. This problem was observed across most of the treatment types and is likely related to stock or other factors, rather than treatment.

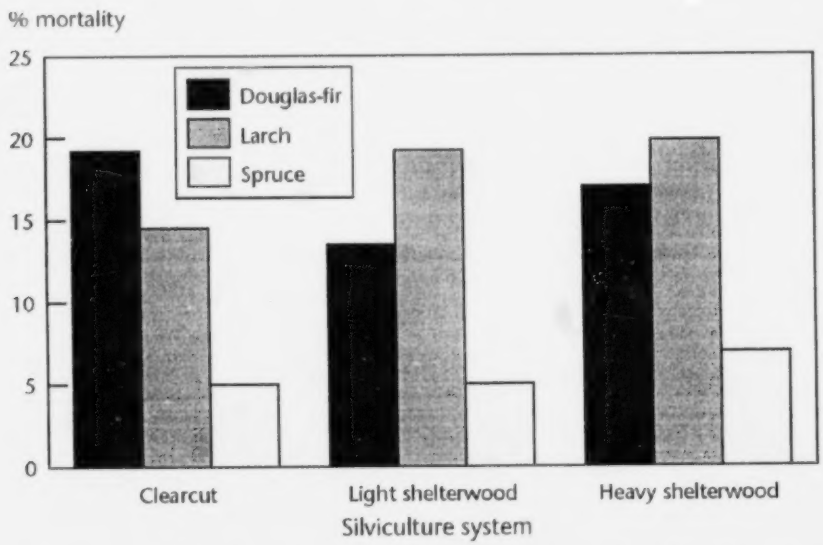

FIGURE 1 *Cumulative mortality of planted seedlings 3 years after harvest at the Mount Seven site.*

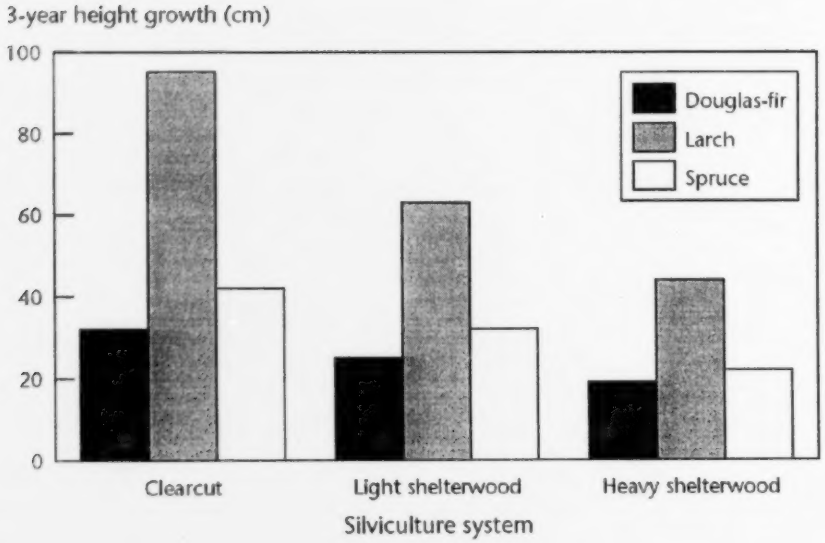

FIGURE 2 *Height growth after three growing seasons at the Mount Seven site.*

Growth Statistically significant differences were observed in height growth between species (Figure 2). Height growth of larch was greater than that of either spruce or Douglas-fir, even in the heavy-retention shelterwoods. This trend is, at least in part, the result of larch growth form. The slightly drier climate and more exposed location compared to the Ice Road site may be contributing to the relatively good growth of larch, and absence of larch needle cast.

Differences in height increment between treatments are not yet significant, but seedlings are beginning to differentiate. It is likely that by the 5-year re-measurement period, differences between treatments will be significant. Analysis of seedling diameter growth showed similar results.

Mount Seven: Advanced Regeneration

Height increment of advanced regeneration will be analyzed after the fifth growing season. Current height of advanced regeneration was compared by species for the different treatments. Results show that species heights between treatments are reasonably similar, so it should be possible to determine treatment-based differences over time.

Mount Seven: Germination

Germination frequency at this site shows considerable variation from year to year, and between treatment types. Both second- and third-year results show an apparent trend towards increasing germination frequency with increasing level of overstorey retention (with the exception of control blocks). In addition, a slight trend was evident towards increased germination on pushover blocks compared to conventionally logged blocks. Heavy-retention shelterwoods had substantially greater germination than other blocks, possibly reflecting the readily available seed supply overhead.

Ice Road: Planted Seedlings

Survival Douglas-fir, western larch, and western redcedar seedlings were planted in sample plots in each

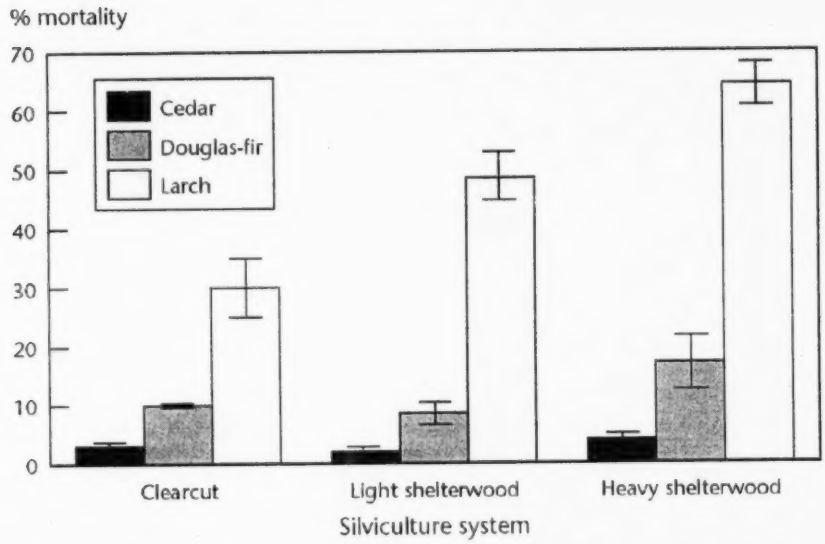

FIGURE 3 *Cumulative mortality of planted seedlings 3 years after harvest at the Ice Road site.*

of the treatment units (except controls) at the Ice Road site. Mortality, vigour, damage, and growth were analyzed after three growing seasons. Results showed statistically significant differences in mortality for the three species, with larch suffering by far the greatest amount (45%), followed by Douglas-fir (11%) and cedar (1%) (Figure 3). Statistically significant differences in mortality were evident between clearcut units and heavy shelterwoods, although no differences between conventionally and pushover-logged units were apparent.

Larch mortality was not consistent across treatment types and the variability suggests that the problem is environmental (treatment-related) rather than stock-related. The likely cause is a foliage disease—probably larch needle cast—observed on most of the surviving seedlings after the second growing season. The seedlings in the shelterwood blocks may have been under stress because of the reduced light conditions and larch needle cast. Therefore, the seedlings may have been more susceptible to mortality over the summer of 1998, especially given the relatively hot, dry weather. The incidence of foliage disease was much lower following the 1998 growing season, so most of the remaining larch seedlings may survive.

Vigour Seedlings of all species show a trend of increasing vigour with decreasing levels of overstorey retention, but the trend is much more pronounced for larch. Western redcedar vigour was predominantly good regardless of treatment type. Douglas-fir vigour was generally good or medium, depending on level of overstorey retention. Only a small proportion of seedlings showed poor vigour. Larch vigour, although still often poor, was greatly improved from 1997 results. The reason for this improvement is likely twofold. In part, it may be due to the high level of mortality over the 1998 growing season (i.e., many of the stems which were previously in poor condition died). In addition, the seedlings were beginning to acclimatize to their new environment.

Damage No serious damage or stress indicators were found on the planted seedlings after three growing seasons, with the exception of thin foliage on some of the larch. This may be related to the larch mortal-

ity at the site. Some additional mortality will likely occur in the larch over the next growing season, as many still show poor vigour and signs of stress (thin foliage); however, mortality is expected to be substantially reduced. Only minor browsing was noted in the third-year assessment.

Growth After three growing seasons, statistically significant differences in seedling growth were evident between species and silvicultural systems, but not between logging method. Seedling height increment was significantly different for all three silvicultural systems. In general, height increment increased as the level of overstorey retention decreased. Results also showed a significant difference in height increment for western redcedar compared to Douglas-fir or larch, with cedar generally showing greater height increment than the other two species.

Figure 4 shows the effects of both species and silvicultural system on height growth, illustrating the effect of poor larch vigour on height growth especially well. Under better conditions, larch should have surpassed Douglas-fir in total height (i.e., given its faster growth form). However, the average height increment of larch is slightly less than that of both Douglas-fir and cedar on the shelterwood sites. Larch was not growing as well as would be expected, even on the clearcut blocks. When larch seedlings are located in favourable microsites they grow very well, but as light levels decrease and other factors such as larch needle cast come into play, growth is substantially reduced.

Diameter growth showed the same trends as height growth, with average diameter growth decreasing as the level of overstorey increased. Differences in diameter growth were statistically significant between all three silvicultural system treatments, and there were significant differences between larch and the other two species.

Ice Road: Advanced Regeneration

A subset of advanced cedar regeneration was used as the sample set for analysis of advanced regeneration at this site. Analysis of variance shows a significant effect of silvicultural system on height increment. Height increment in control blocks is significantly different from that of clearcut and light

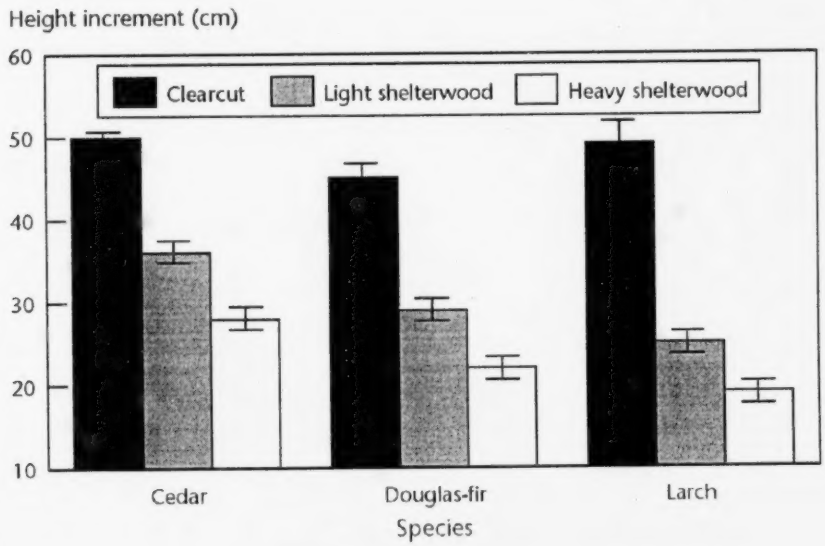

FIGURE 4 *Height increment of planted seedlings 3 years after harvest at the Ice Road site.*

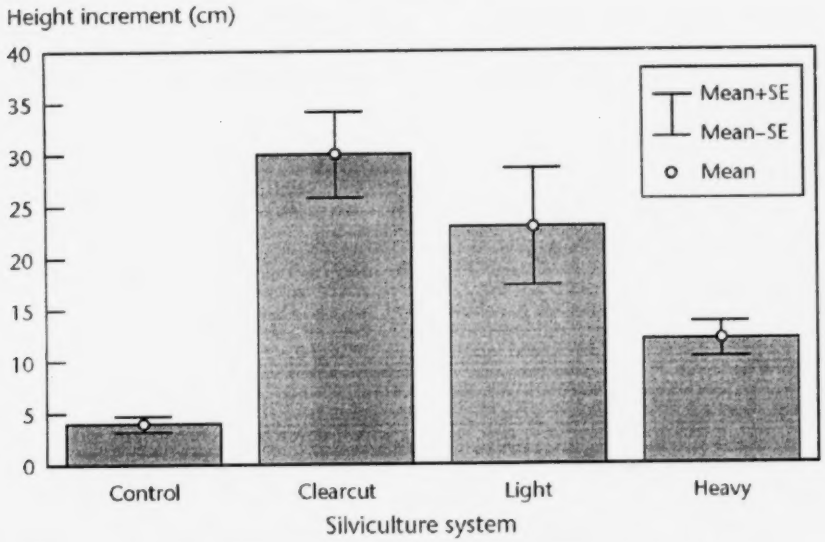

FIGURE 5 *Three-year height increment of advanced cedar regeneration at the Ice Road site.*

shelterwood blocks, and height increment in heavy shelterwoods is significantly different from that in clearcuts (Figure 5).

Ice Road: Germination

No trends are obvious to relate germination occurrence to either logging method or level of overstorey retention. Substantial variation was evident in germinant occurrence within each treatment.

REFERENCES

Comeau, P. and K. Thomas. 1998. Evaluation of understory light conditions using fisheye photography at Ice Road (EP 1186). Research Branch, B.C. Ministry of Forests, Victoria, B.C.

DeLong, D.L. 1995. Shelterwoods in root disease infected stands: preliminary results (EP 1186). B.C. Ministry of Forests, Nelson, B.C. Research Summary RS-023.

Nelson Forest Region. 1996. Shelterwood harvesting in root disease infected stands (EP 1186): preliminary results, Ice Road site. B.C. Ministry of Forests, Nelson, B.C. Research Summary RS-030.

Nelson Forest Region. 1999. Using partial-cutting systems in root-disease infected stands in the interior ICH zone: EP 1186 progress report to March 1999, study component #2: Regeneration response, 3rd year results, Ice Road Site. B.C. Ministry of Forests, Nelson, B.C.

Prescott, C., L. Blevins, and C. Staley. 1999. Rates of litter decomposition in the silvicultural systems trials at Mount Seven and Ice Road: progress report. Department of Forest Sciences, University of B.C., Vancouver, B.C.

AUTHORS

* ***Correspondence to:*** Deb DeLong, B.C. Ministry of Forests, Nelson Forest Region, 518 Lake Street, Nelson, BC V1L 4C6.

E-mail: Debbie.Delong@gems6.gov.bc.ca

† B.C. Ministry of Forests, Research Branch

‡ Department of Forest Sciences, University of British Columbia

Retrospective studies of soil conditions and forest productivity on rehabilitated landings: Interior of British Columbia

MATTHEW PLOTNIKOFF*, MARGARET SCHMIDT†, AND CHARLES BULMER‡

INTRODUCTION

In British Columbia, forest soil rehabilitation aims to restore productivity to roads and landings that are no longer needed, and to areas that have suffered unavoidable or accidental damage. Soil rehabilitation is often an important component of management strategies to maintain or enhance timber supply in the working forest. Restoring productivity to degraded soils also enhances other environmental values, which contribute to successful ecosystem or watershed restoration.

Soil rehabilitation research was initiated in British Columbia over two decades ago (Vyse and Mitchell 1977), and numerous contributions since that time have been reviewed by Bulmer (1998) and Sanborn et al. (1999). Despite significant progress in the past, and new information expected in the future, more information is required to guide current operational projects. In particular, information is needed on the long-term effectiveness of soil rehabilitation efforts, and the extent to which operational rehabilitation projects can contribute to the timber supply.

We examined tree growth and soil conditions on sites that were rehabilitated in 1991 in the Interior Cedar–Hemlock (ICH) biogeoclimatic zone. The objectives were:

- to document at least 5-year growth of lodgepole pine on rehabilitated landings, and compare it to growth on sites that were simply harvested; and
- to document soil conditions affecting site productivity on the rehabilitated areas.

MATERIALS AND METHODS

We sampled 98 landings and areas in the adjacent plantations in three forest districts. The landings were tilled with a winged subsoiler in the early 1990s as part of operational rehabilitation programs. To evaluate forest productivity and soil conditions on the landings and adjacent areas, we:

- located randomly three 0.005-ha plots on each landing, and three in the adjacent plantation;
- measured height and all increments of lodgepole pine within the plots (maximum five trees per plot in plantations), and recorded the abundance of all tree species in three age groups;
- measured soil temperature, moisture, forest floor depth, and probe penetration depth;

Citation —

Plotnikoff, M.P., M.G. Schmidt, and C.E. Bulmer. 2000. Retrospective studies of soil conditions and forest productivity on rehabilitated landings: Interior of British Columbia. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 113–17.

- evaluated soil texture, total C, total N, mineralizable (available) N, bulk density, and pH; and
- collected foliage samples and analyzed them for nutrient content.

RESULTS AND DISCUSSION

Figure 1 shows that 63–95% of the time (in the Boundary and Kispiox forest districts, respectively), the plots we sampled on landings had greater than 1000 stems per hectare. The average stocking level (all lodgepole pine trees greater than 15 cm tall) was approximately 1450 stems per hectare. These results indicate that planting pine on landings, which were tilled with a winged subsoiler, has led to successful establishment of a new forest most of the time.

In the Boundary Forest District (Figure 2), trees growing on rehabilitated landings were growing as well or better than trees in the adjacent plantations. In the northwestern forest districts (Figures 3, 4), tree heights were generally lower for the rehabilitated landings, in comparison to the adjacent plantations.

Trees growing in the plantations in the Kispiox and Kalum forest districts were growing at similar rates, but the trees on rehabilitated landings in the Kalum Forest District were much larger. Factors that may explain the apparent difference in rehabilitation success include:

- seedlings planted in Kalum Forest District were bigger, and from copper-coated styroblocks;
- fertilizer was used in the Kalum Forest District to assist the establishment of seeded cover crops; and
- subsoiling in the Kispiox Forest District was less effective.

Trees were growing more slowly in the plantations in the Boundary Forest District than in the other districts. Trees on landings in the Boundary Forest District also tended to be younger than those in the other districts, which reflects fill-planting associated with some initial establishment problems. Many more naturally established trees occurred on the landings in the Boundary Forest District.

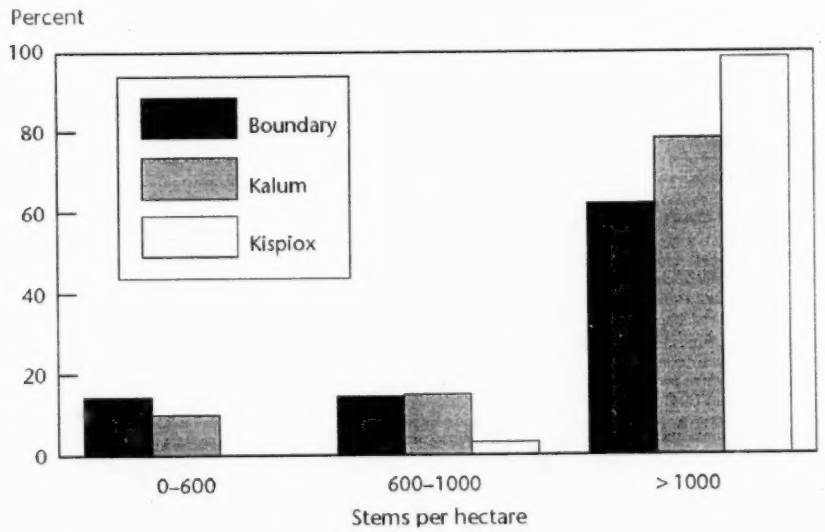

FIGURE 1 *Stocking rates for landings in three districts.*

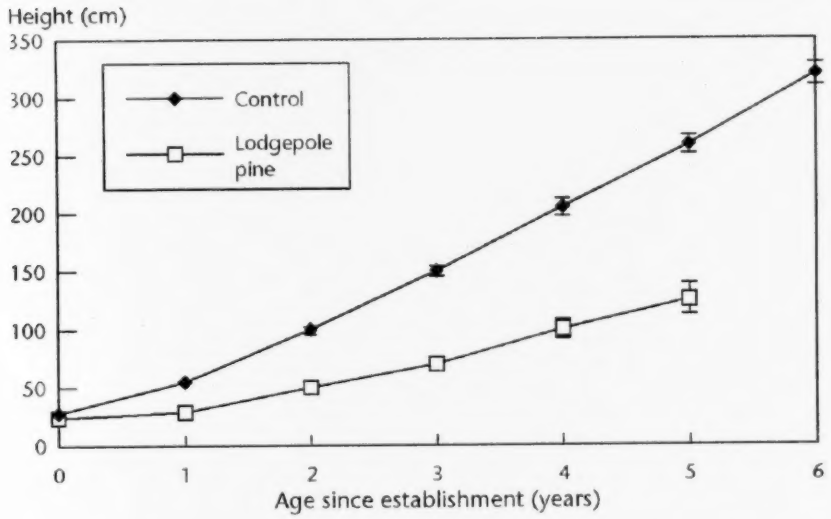

FIGURE 2 *Lodgepole pine growth on landings and plantations in Kispiox District (n = 32).*

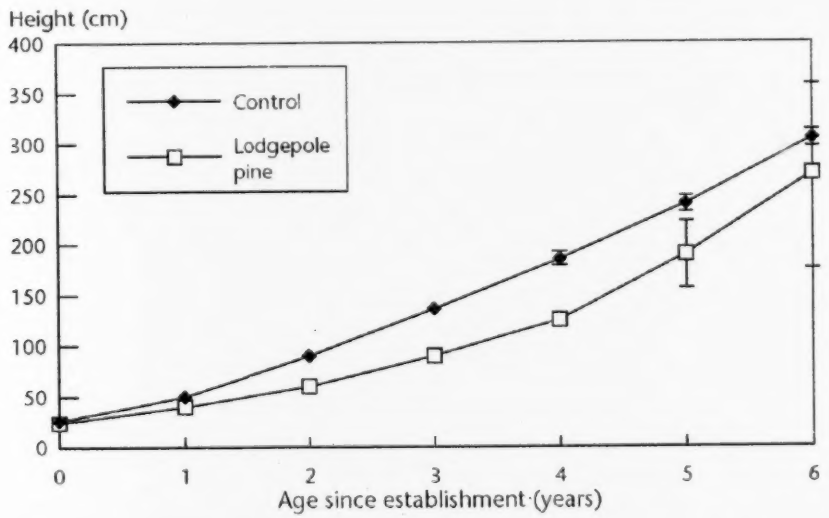

FIGURE 3 *Lodgepole pine growth on landings and plantations in Kalum District (n = 25).*

In all three districts, landings were warmer and drier than plantation sites. For all districts, average soil bulk density was below growth-limiting values for both landings and plantations. Landings tended to have less C and mineralizable N in all districts, but the differences were smaller for the Kalum Forest District. For the Kispiox Forest District, mineralizable N values on landings were substantially lower than the values for plantation sites. Differences in C and nutrients likely reflect the absence of topsoil on the rehabilitated landings.

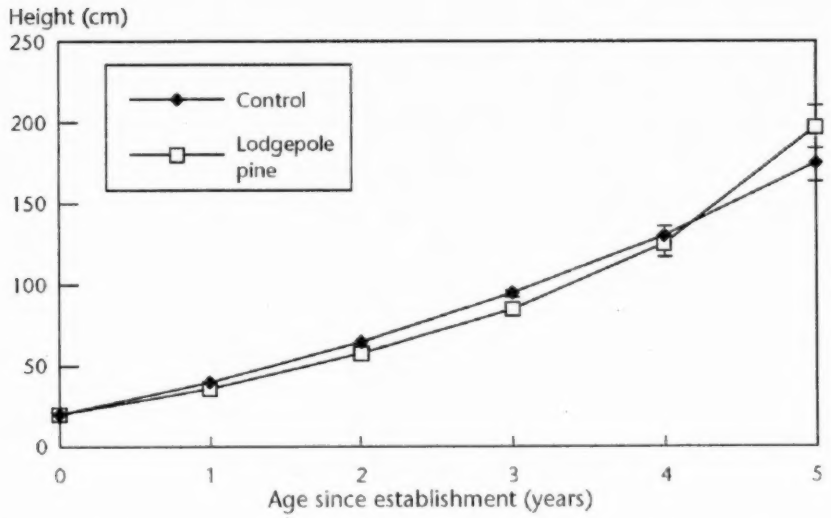

FIGURE 4 *Lodgepole pine growth on landings and plantations in Boundary District (n = 41).*

Foliar nutrient concentrations, determined for a subset of 10 landings and plantations in each district, were generally adequate for most nutrients (Ballard and Carter 1984).

SUMMARY

- Early indications are that, even without spreading topsoil, rehabilitating these landings has resulted in good stocking.
- Observed productivity suggests that a commercial tree crop will likely result.
- Modern rehabilitation techniques with topsoil spreading would likely result in even better growth than we have found in our study.

REFERENCES

Ballard, T.M. and R.E. Carter. 1984. Evaluating forest stand nutrient status. B.C. Ministry of Forests, Victoria, B.C.

Bulmer, C.E. 1998. Forest soil rehabilitation in British Columbia: a problem analysis. B.C. Ministry of Forests, Victoria, B.C. Land Management Handbook No. 44.

Marsland, M. 1994. Review of the Kispiox and Kalum landing and skidroad rehabilitation program. Kispiox District, B.C. Ministry of Forests, Hazelton, B.C. Internal Report.

Sanborn, P., M. Kranabetter, and C. Bulmer. 1999. Soil rehabilitation in the Prince George Forest Region: Lessons from two decades of research. B.C. Ministry of Forests, Prince George, B.C. Extension Note No. PG-16.

Vyse, A. and W. Mitchell. 1977. Rehabilitating landings in the Cariboo Forest District. B.C. Ministry of Forests, Williams Lake, B.C. Research Brief No. 6.

AUTHORS

* ***Correspondence to:*** **Matthew P. Plotnikoff**, Department of Geography, Simon Fraser University, 8888 University Drive, Burnaby BC V5A 1S6.

E-mail: mplotnikoff@arts.sfu.ca

† Department of Geography, Simon Fraser University

‡ B.C. Ministry of Forests, Research Branch

Litter decomposition in British Columbia forests: Influences of forestry activities

CINDY PRESCOTT* AND LEANDRA BLEVINS†

INTRODUCTION

The decomposition of litter and subsequent release of nutrients in plant-available forms is an essential process in the functioning of forest ecosystems. Temperature, moisture, and litter chemistry control decomposition rates through their influences on the activity of soil organisms. Forestry activities that influence the microclimate or nature of the litter can alter decomposition rates.

There are several commonly held beliefs about rates of litter decomposition. Using a suite of field experiments across the province, we tested the applicability of these "well-known facts" to decomposition in British Columbia forests. We asked the following questions:

1. Is decomposition slower in cold (northern and high-elevation) forests?
2. Is decomposition faster in clearcuts than in forests?
3. Does broadleaf litter decompose faster than needle litter?
4. Is decomposition faster in N-fertilized forests?

MATERIALS AND METHODS

Litterbags were used in all experiments. A known dry weight of litter was enclosed in a mesh bag and the weight remaining was measured annually for 3–5 years.

Question 1: Decomposition Rates in Biogeoclimatic Zones

Rates of decomposition of standard litter substrates (lodgepole pine needle litter, trembling aspen leaf litter, and forest floor material) were measured at 26 sites in nine biogeoclimatic zones across the province. Seven bags of each substrate were collected from each site annually for 4 years (pine and forest floor) or 3 years (aspen), and the dry weight of material remaining in each bag was measured.

Question 2: Decomposition Rates in Forests and Clearcuts

Experiments were established at 14 sites in seven biogeoclimatic zones across the province. Litterbags containing pine needle litter, aspen leaf litter, and forest floor material were installed in a forest and in an adjacent clearcut. Seven bags of each material were collected from each location annually, and the dry mass of material remaining in the forests and clearcuts were compared.

Citation —

Prescott, C.E. and L.L. Blevins. 2000. Litter decomposition in British Columbia forests: influences of forestry activities. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 119–21.

Question 3: Decomposition Rates of Broadleaf and Needle Litter

Foliar litter of 14 tree species (lodgepole pine, western white pine, ponderosa pine, western hemlock, western larch, Engelmann spruce, subalpine fir, western redcedar, Douglas-fir, amabilis fir, trembling aspen, black cottonwood, red alder, and vine maple) were collected at sites across the province. Mass loss of leaf litter of each species was measured for 5 years at the University of British Columbia Research Forest near Maple Ridge, B.C.

Decomposition of aspen leaf litter and spruce needle litter (both pure and mixed) was compared for 5 years at four sites near Dawson Creek, B.C. The decomposition of red alder leaf litter and Douglas-fir needle litter (both pure and mixed) was compared for 3 years in three pure plots of Douglas-fir and of red alder at the University of British Columbia Research Forest near Maple Ridge, B.C.

Question 4: Decomposition Rates in Fertilized Forests

Rates of decomposition were measured in control and N-fertilized plots of trembling aspen near Chetwynd, B.C. and coastal Douglas-fir near Seattle, Washington.

RESULTS AND DISCUSSION

Question 1: Decomposition Rates in Biogeoclimatic Zones

Mass loss of lodgepole pine needle litter after 4 years was greatest in the Coastal Western Hemlock (CWH) and Interior Cedar–Hemlock (ICH) zones and least in the Ponderosa Pine (PP) followed by the Boreal White and Black Spruce (BWBS) zone. The other five zones (Mountain Hemlock [MH], Coastal Douglas-fir [CDF], Interior Douglas-fir [IDF], Sub-Boreal Spruce [SBS], and Engelmann Spruce–Subalpine Fir [ESSF]) had intermediate rates of decomposition. In aspen leaf litter, mass loss after 3 years was greatest in the CWH followed by the MH zone. The slowest decomposition of aspen was in the PP, followed by the BWBS and IDF zones. Forest floor material decomposed slowly without much differentiation among the zones. These results indicate that within the range of climates in the province, decomposition is most affected by moisture.

Question 2: Decomposition Rates in Forests and Clearcuts

Mass loss of pine needles was slower, or the same, in clearcuts after 3 years. Mass loss of aspen leaf litter varied widely among sites with no consistent differences between clearcuts and forested sites.

Question 3: Decomposition Rates of Broadleaf and Needle Litter

Only leaf litter of vine maple decomposed faster than needle litter. Broadleaf litter lost mass faster during the first year, but then more slowly, such that mass loss was similar after 3 years. In the mixture experiments, aspen lost mass faster during the first year and then more slowly than spruce, so differences were small after 3 years. Alder leaf litter decomposed faster than Douglas-fir during the first 6 months, but no differences were evident after 1 year. There was no evidence in either experiment that mixing with broadleaf litter hastened decomposition of the needle litter.

Question 4: Decomposition Rates in Fertilized Forests

For both Douglas-fir and aspen, litter from N-fertilized and control plots decomposed at the same rate, as did litter incubated in fertilized and control plots.

In conclusion, our studies in British Columbia forests suggest that:

1. Decomposition in provincial forests is more closely related to moisture than temperature.
2. Decomposition is no faster in clearcuts than in forests.
3. Broadleaf litter does not decompose faster than needle litter after the first year.
4. Fertilization does not increase decomposition rates.

Decomposition rates are determined by a few very fundamental factors, so the effects of forest management activities can only be predicted by assessing, on a site-specific basis, how the activity will affect each of these factors. Generalizations about the effects of forest opening, fertilization, or species mixtures are inappropriate. These findings are contrary to several commonly held beliefs about decomposition rates and demonstrate the need for research conducted in British Columbia to support forest management decisions.

AUTHORS

* ***Correspondence to:*** **Cindy E. Prescott**, Department of Forest Sciences, University of British Columbia, 3041-2424 Main Mall, Vancouver, BC V6T 1Z4.

E-mail: cpres@interchg.ubc.ca

† Department of Forest Sciences, University of British Columbia

Effects of opening size on soil ecology and nutrient cycling in a high-elevation, southern Interior forest

GRAEME HOPE[*], RALPH ADAMS[†], DANIEL DURALL[‡], SHANNON HAGERMAN[‡], GARY HUNT[§], KATHLEEN JOHNSON[‖], MELANIE JONES[‡], HANNAH NADEL[‖], CINDY PRESCOTT[#], DONALD SACHS[‖], SYLVIA WELKE[‖], AND MICHAEL FELLER[#]

INTRODUCTION

The Sicamous Creek Silvicultural Systems Project was established to provide the forestry community with information on the ecology and responses to disturbance of high-elevation, Engelmann Spruce–Subalpine Fir (ESSF) forests in the southern Interior of British Columbia. Forty-five separate projects have been established at the site. These projects are in the broad areas of harvest logistics, forest dynamics, microclimate and hydrology, soils and nutrient cycling, tree regeneration and growth, flora, fauna, and habitat attributes. The intent is to create a comprehensive and integrated information base to help manage silvicultural systems in these forests.

Soil projects were established with two major aims:

1. to gain an understanding of the properties and processes affecting soil productivity in the forests; and
2. to understand the effects of canopy disturbance on those processes.

Soil organic matter appears to be the main soil component affected by harvesting in the ESSF zone because much of the harvesting takes place on a protective snowpack. In addition, soil biological activity and microclimate control many of the soil processes involving organic matter. These properties are consequently the focus of numerous soil-related studies at Sicamous Creek.

MATERIALS AND METHODS

The study area is located in the Hunter Range southeast of the town of Sicamous, in the Salmon Arm Forest District. The site is in the Engelmann Spruce–Subalpine Fir wet cold biogeoclimatic subzone (ESSFwc2), at an elevation of 1500–1800 m. Soils on the site are predominantly sandy loam-textured Orthic Humo Ferric Podzols. These soils occur on mesic and submesic site series. On wetter areas, soils are Gleyed Sombric Brunisols and Orthic Gleysols. Forest floors average 4 cm throughout the site (range: 1–14 cm) and contain approximately 10–30% decayed wood. Humus forms are predominantly Hemimors.

Citation —

Hope, G.D., R.S. Adams, D.M. Durall, S.M. Hagerman, G.A. Hunt, K.A. Johnson, M.D. Jones, H. Nadel, C.E. Prescott, D.L. Sachs, S.E. Welke, and M.C. Feller. 2000. Effects of opening size on soil ecology and nutrient cycling in a high-elevation, southern Interior forest. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 123–26.

Harvesting created five different opening types or sizes. Each treatment is replicated three times in a randomized block design separated by buffers of mature forest. Treatments included control, single-tree selection, and 0.1-, 1.0-, and 10-ha openings. The site was harvested in the winter of 1994/95 and site prepared the following summer. All openings were planted in the summer of 1996.

Table 1 provides a summary of soil-related projects established at Sicamous Creek.

TABLE 1 *Soil and nutrient studies at Sicamous Creek*

Study leaders	Focus	Parameters measured	Sampling locations	End products
Hope, Prescott, and Sachs	Organic matter and nitrogen dynamics	Soil C, N and S; N mineralization; litter decomposition; N uptake by seedlings	All treatments; plus transects in one 10-ha block	Soil nutrient budgets; N turnover rates; long-term C and N predictions
Johnson and Hope	Soil food webs and nitrogen dynamics	Total soil bacteria, fungi, and nematodes; N mineralization and denitrification	Control, 0.1 ha, and 10 ha	Food web biomass, N dynamics in the root zone
Jones, Durrall, and Hagerman	Ectomycorrhizal diversity and fungal sporocarps	Live ectomycorrhizal root tips; soil bioassays; sporocarp biomass and identification	Control, 0.1, 1.0, and 10 ha; plus transects in three 10-ha blocks	Number or biomass, and diversity of ectomycorrhizae and sporocarps
Hunt and Welke	Fine roots	Fine root biomass, nutrient content; and decomposition	Control, 0.1, 1.0, and 10 ha; plus transect in one 10-ha block	Nutrient capital and fluxes from fine roots
Nadel	Soil micro-arthropods	Mites and collembola; numbers and diversity	Control, 0.1, 1.0, and 10 ha; plus transect in one 10-ha block	Abundance and diversity of mites and collembola
Adams	Microclimate	Soil temperature	Transects in one each of the 0.1-, 1.0-, and 10-ha blocks	Models of edge effects on temperature
Prescott	Litter and coarse woody debris inputs	Annual litter and dead wood inputs	Control	Rates of input
Feller	Nutrient budgets, nitrogen fixation	Nutrients in precipitation and soil leachate; N fixation and denitrification	One control and one 10 ha block	Nutrient budget, gaseous N fluxes

RESULTS

Results presented here are for 2, 3, and 4 years after harvest.

Effects of Harvesting

The most dramatic decrease was in hypogeous sporocarp (truffle) biomass. Significant decreases were also observed in fungal biomass, numbers and diversity of active mycorrhizae, and fine-root biomass. Total and active fungal biomass, but not total bacterial biomass, decreased in the forest floor in the 1.0- and 10-ha openings ($p \leq 0.1$). Increases occurred in soil temperature, nitrogen mineralization, and denitrification (loss of nitrate as gaseous N) potential. Total bacterial biomass, nematodes, and mineral soil microbial biomass were insignificantly affected. Micro-arthropod abundance, but not diversity, was also reduced. Partial cutting did not significantly affect the low rate of nitrogen fixation (< 1 kg/ha per year) occurring in undisturbed forests.

Influence of Opening Size

Rates of inorganic N production (mineralization and nitrification) increased with increased opening size up to 1.0 ha in the second year. In the third year, any canopy disturbance increased both inorganic N and the proportion of nitrate. Increased mineralization was not accompanied by faster decomposition of litter or forest floor.

After two and three growing seasons, all opening sizes showed the same decrease in the richness of ectomycorrhizae away from forested edges into the openings. In the spring (but not in the fall) two and three years after harvest, some measures of fine-root biomass showed significant differences between openings. Two years after harvest, the collective abundance of soil micro-arthropods and the diversity of mites and collembola showed no significant change with opening size, although one group (the Collembola) do show a trend of being affected by cut size.

Changes Away from the Forested Edge

On hot, clear days, any change in temperature occurred very close to the forest edge on the opening side (< 12 m). On such days, variations across the edges are most pronounced. A general increase occurred in N mineralization from the south to the north edge of the 10-ha clearcut in both the first (statistically significant) and second (non-significant) years after harvest. Two and three growing seasons after logging, the richness of ectomycorrhizal types colonizing young, initially non-mycorrhizal seedlings, was significantly greater within 2 m from the forest edge compared to plots farther out into the openings. A significant difference in fine-root biomass along the 10-ha transects also occurred.

CONCLUSIONS

We arrived at the following conclusions.

- Increases in soil temperature and nitrogen availability, which improve early seeding establishment and growth after harvesting, are no greater in 10-ha cuts than 1-ha cuts.
- Site nitrogen should be conserved wherever possible because nitrogen inputs (fixation, precipitation) are low, and possible losses through nitrate leaching and denitrification may occur after harvesting (e.g., in tops, branches, and forest floor).
- Soil biological parameters are affected differentially by harvest and time after harvest, by opening size, and by the distance from the forest edge into the opening.

AUTHORS

* ***Correspondence to:*** **Graeme D. Hope,** Kamloops Forest Region, B.C. Ministry of Forests, 515 Columbia Street, Kamloops, BC V2C 5E1.

E-mail: graeme.hope@gems3.gov.bc.ca

† B.C. Ministry of Forests, Research Branch
‡ Biology Department, Okanagan University College
§ Natural Resource Science Department, University College of the Cariboo
‖ Private consultant
Department of Forest Sciences, University of British Columbia

Volume loss of Douglas-fir infected with *Armillaria ostoyae*

MIKE CRUICKSHANK*

INTRODUCTION

Armillaria root disease is responsible for mortality of all types of woody plant species worldwide. The effects of non-lethal infection on the roots of these same woody species are less well known. As early as 1874, Robert Hartig published a description of the infection process that included observations on reduced annual height and ring width, and the difficulty of identifying symptoms of root infections above ground. Over the range of the fungus in southern British Columbia, the Interior Cedar–Hemlock biogeoclimatic zone (ICH) is the most affected area. In this ecosystem, the background level of below-ground infection of juvenile trees ranges from about 15% in non-symptomatic areas to about 35% near trees with symptoms (Morrison et al. 1999). In older stands, the infection rate in non-symptomatic stands can range as high as 80%. In all stands, the incidence of infection increases with tree size.

Previous studies indicate that growth loss occurs upon root contact with inoculum of all root diseases. Losses due to Armillaria species are probably the highest given its wide distribution and its ability to spread via root contacts and rhizomorphs. Volume losses in old-growth Interior Douglas-fir are estimated to be 1% per year starting at age 50 (Bloomberg and Morrison 1989). The epidemiology in planted juvenile stands is expected to be different from old-growth stands because silvicultural practices alter the development of the disease. This study documents the epidemiology of Armillaria root disease in juvenile stands and determines what effect non-lethal root infections might have on our young trees at one site near Kaslo, B.C.

METHODS

Eighteen-year-old Douglas-fir trees were pulled out of the ground using a pop-up spacer so that roots and tops were intact. The root system of each tree was surveyed for presence of *Armillaria ostoyae* infection (fans). The roots were sectioned at the root collar and proximal to each infection to determine the infection date. The infection date for a tree was the oldest infection. The proportion of infected roots per tree was calculated using main lateral roots only (> 15 mm).

Top measurements were taken of height increment for the past 10 years, and stem cross-sectional disks were taken at the soil line and at breast height. Stem cross-sectional area was marked for the first 10 years, and then 4-year periods after that. This information was then digitized. Volume was calculated using the area and height measurements.

All analyses were performed using SAS (PROC GLM). The analysis for volume reduction used final volume as the dependent variable, with initial volume, infection age classes, and proportion of infected

Citation —

Cruickshank, M. 2000. Volume loss of Douglas-fir infected with *Armillaria ostoyae*. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 127–9.

roots as independent variables. The infection classes consisted of no infection, infected 1–4 years ago, and infected 5–8 years ago.

RESULTS

Infection date and proportion of infected roots does affect cross-sectional area at breast height. Trees were initially infected at about age 5 and infection peaked at about age 14. Tree radial growth before infection showed that the dead trees had been growing more quickly (about 25%) than the others. Losses accumulated shortly after infection and were positively correlated with increasing time and percentage of infected roots.

Disease affected cumulative height in a similar way. Dead trees had greater height growth before infection and greater loss occurred with increasing time and infection. Even within dead trees, death occurred sooner when the trees were growing more rapidly in the first 10 years.

Table 1 shows parameters important for modelling volume loss. The initial volume was the most important main effect in the model. Infection period, not significant as a main effect, interacts with initial volume (A × B). This interaction indicates that trees initially growing more rapidly show more volume loss with increasing time since infection than smaller trees (about 40% over 4–8 years). The proportion of infected roots was marginally significant as a main effect. No other interactions were significant.

CONCLUSIONS

This analysis of growth reduction indicates that time since infection is more important than the amount of infection a root system has sustained. Soon after a main lateral root becomes infected, the effect of loss can be detected in the stem. This effect lasts at least 8 years. Larger trees loose more volume than smaller trees probably because they are putting on more increment. Volume reduction could occur because of loss of vascular tissue, loss of energy to defense, or replacement of new tissues such as callus and new roots.

Heavily infected trees do not show a period of appreciable volume loss because they become girdled and die quickly. Why increased growth and mortality seemed related is not clear; however, these

TABLE 1 *Analysis model for the final volume of infected and uninfected trees*

	Parameter		
	F	*P*	R^2
Model	30	0.0001	0.64
Independent variables:			
A: initial volume before infection	224	0.0001	
B: infection period	1.27	0.2837	
C: proportion of infected roots	3.17	0.0770	
A × B	8.7	0.0003	
A × C	2.16	0.1258	
B × C	0.93	0.3370	
A × B × C	0.62	0.4313	

characteristics have been noted by others (Hrib et al. 1983). Faster-growing trees may die more quickly because they touch the stump inoculum sooner when the fungus is at a higher inoculum potential, or they allocate less energy to defense.

These results indicate that Armillaria root disease in the Interior affects larger, more vigorous juvenile trees more strongly in many ways. Many silvicultural techniques aim to increase the growth of the trees in the first 20 years; consequently, trees become infected sooner, and all tree species are susceptible at this time. Techniques such as brushing and weeding, planting, burning, and juvenile spacing (and more recently breeding) all shorten the time to contact with stump inoculum. Furthermore, harvesting increases the volume of inoculum on-site because the fungus can colonize the stumps and spread to the surrounding crop trees.

This study relates loss to individual trees; however, at the stand level, losses should be proportional to the area of stand infected. The high level of root infection in the ICH (mostly undetectable) probably ensures that the full potential of these sites is not being realized. Increased growth of surrounding trees may occur near centre openings, if the edge trees do not become infected. This is a large assumption and recent evidence (Morrison et al. 1999) suggests that the incidence of infection around a dead or infected tree is higher than in non-symptomatic areas and that larger trees are more likely to become infected. The effect of non-lethal infections (the highest fraction) at stand level remains. These trees provide competition for many years. Stands in which trees are progressively infected over the rotation should reach a given volume later than stands without disease. Given the wide distribution of this fungus in Canada and worldwide, and the potential to amplify the inoculum by forest activities, the long-term threat to forest productivity is considerable.

REFERENCES

Bloomberg, W. J. and D.J. Morrison. 1989. Relationship of growth reduction in Douglas-fir to infection by Armillaria root disease in the Southeastern British Columbia. Phytopathology 79:482–7.

Hartig, R., 1874. Important diseases of forest trees. *In* Phytopathological classics No. 12, 1975. American Phytopathology Society.

Hrib, J., J. Kyncl, and A. Cerny. 1983. A tree-ring study of Norway spruce infected with the wood-destroying fungus *Armillaria mellea*. Journal of Forest Pathology 13:160–5.

Morrison, D.J., K.W. Pellow, D.J. Norris, and A.F.L. Nemec. [1999] Visible versus actual incidence of Armillaria root disease in juvenile coniferous stands in the southern interior of British Columbia. In preparation.

AUTHOR

• ***Correspondence to:*** **Mike Cruickshank**, Canadian Forest Service, 506 West Burnside Road, Victoria, BC V8Z 1M5.

E-mail: mcruicks@pfc.forestry.ca

Potential of woody understorey plants to provide refuge for ectomycorrhizal inoculum at an Interior Douglas-fir forest after clearcut logging

SHANNON HAGERMAN*, STACEY SAKAKIBARA†, AND DANIEL DURALL†

INTRODUCTION

Ectomycorrhizal fungi take up and transport essential nutrients to their host plants (Harley and Smith 1983). The ectomycorrhizal association may, therefore, be important for the adequate growth and survival of many tree species at both early and late stages of development (Christy et al. 1982; Perry et al. 1987). However, silvicultural systems such as clearcut logging can result in a reduction in quantity and diversity of ectomycorrhizal fungal inoculum (Harvey et al. 1980; Parsons et al. 1994; Hagerman et al. 1999). Thus, seedlings grown in areas of clearcut logging often form less ectomycorrhizae than seedlings grown in undisturbed soils (Perry et al. 1982; Parke et al. 1984). Furthermore, the dispersal of spores into disturbed areas may be insufficient to provide inoculum at levels comparable to the uncut forest (Perry et al. 1987). After clearcut logging, some plant species previously present underneath the canopy persist and proliferate throughout an opening. Many of these plant species form mycorrhizal associations with ectomycorrhizal fungi and have the potential to act as reservoirs for ectomycorrhizal fungal inoculum, which would otherwise die because of the lack of a plant associate. These plant species are referred to as "refuge plants."

The alternative silvicultural systems trials at Opax Mountain aimed to gain a better understanding of the effects of various harvesting methods on the ecology and management of Interior-Dry Douglas-fir forests in British Columbia. The objectives of this part of the Opax study were:

- to identify understorey plants that could support ectomycorrhizal fungal inoculum for Douglas-fir seedlings outplanted in the clearcuts; and
- to quantify the diversity (expressed as richness) of ectomycorrhizae associated with refuge plants amongst each other and at clearcut and forest locations.

MATERIALS AND METHODS

The Opax Mountain Silvicultural Systems Trial is located in the southern Interior of British Columbia and ranges in elevation from 950–1370 m (Bealle-Statland 1998). The site was harvested in the winter of 1993–1994. The alternative silvicultural systems implemented included single-tree selection, as well as patch cuts ranging in size from 0.1, 0.4, and 1.6 ha in a randomized block design. This study was

CITATION —

Hagerman, S.M., S.M. Sakakibara, D.M. Durall. 2000. Potential for woody understorey plants to provide refuge for ectomycorrhizal inoculum at an Interior Douglas-fir forest after clearcut logging. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 131–5.

conducted in the three upper-elevation, 1.6-ha patch-cut treatment units (and adjacent uncut forest) and at the three lower-elevation patch-cut treatment units (and adjacent uncut forest).

Roots from 16 species of common woody understorey plants (Table 1) were sampled from the uncut controls in July 1995 to assess their ectomycorrhizal status. Ectomycorrhizal and arbutoid mycorrhizal roots were described and identified according to specific morphological features and molecular characteristics (PCR/RFLP analysis). Based on the preliminary screening of the 16 potential refuge plants sampled in 1995, a subset of the most extensively colonized species was selected for further analysis in 1996, 1997, and 1998.

Diversity is expressed as richness, where richness is the number of morphotypes encountered (at the scale of the individual plant; $n = 200$ mycorrhizae). The effect of treatment (clearcut vs. forest) on the richness of the mycorrhizal community was tested by one-way ANOVA.

RESULTS AND DISCUSSION

Colonization by ectomycorrhizal fungi was observed for 11 of 16 plant species surveyed (Table 1). Although many of the plants assessed were extensively associated with ectomycorrhizal fungi, *Arctostaphylos uva-ursi* and advanced regeneration seedlings of Douglas-fir had a high proportion of fine roots colonized by ectomycorrhizal fungi. These species were also abundantly distributed throughout the study site. Therefore, we considered these two plant species particularly good candidates to provide refuge for ectomycorrhizal fungi after logging. Additionally, *A. uva-ursi* forms extensive mats throughout the openings, but does not shade out young conifer seedlings.

TABLE 1 *Ectomycorrhizal status of 16 understorey plant species sampled from the Opax mountain site in July of 1995*

Plant species	% colonization	No. of morphotypes observed	No. of morphotypes shared with Douglas-fir
Acer glabrum	0.00 ± 0.00	—	—
Alnus viridis	48.12 ± 7.60	8	8
Amelanchier alnifolia	17.11 ± 9.53	5	4
Arctostaphylos uva-ursi	34.99 ± 6.33	17	10
Betula papyrifera	56.01 ± 10.04	13	8
Chimaphila umbellata	0.00 ± 0.00	—	—
Juniperus communis	0.00 ± 0.00	—	—
Mahonia aquifolium	0.00 ± 0.00	—	—
Paxistima myrsinites	1.03 ± 1.03	1	1
Populus tremuloides	44.52 ± 6.80	16	11
Pseudotsuga menziesii	46.78 ± 9.24	15	
Salix commutata	25.38 ± 5.99	14	7
Shepherdia canadensis	15.16 ± 7.79	8	4
Spirea betufolia	0.99 ± 0.99	2	2
Vaccinium caespitosum	0.97 ± 0.97	1	1
Vaccinium membranaceum	0.00 ± 0.00	—	—

Over all years of the study, 29 and 33 morphotypes were described for Douglas-fir and *A. uva-ursi*, respectively. Twenty-seven types were shared by both species. A shared community of ectomycorrhizal fungi may contribute to the regeneration success of Douglas-fir. This was the conclusion of Horton et al. (1999), who investigated Douglas-fir regeneration in proximity to *Arctostaphylos* in a chaparral community on the central coast of California.

Other plant species, such as *Betula papyrifera, Populus tremuloides, Alnus viridis,* and *Salix commutata,* were patchily distributed throughout the site, yet hosted a diverse community of ectomycorrhizal fungi. Therefore, we also considered these plants as important for providing refugia.

DIVERSITY OF THE MYCORRHIZAL COMMUNITY

Refuge plants may be important for maintaining a diverse ectomycorrhizal community. Because the quantity and diversity of some types of ectomycorrhizal inoculum can decrease after clearcut logging, this community will be available to outplanted seedlings. In the latter two years of the study, *A. uva-ursi* exhibited similar levels of mycorrhizal diversity in both forest and clearcut plot locations (Figure 1). This observation is important because many researchers suggest that seedlings associated with a diverse array of ectomycorrhizal fungi may be better able to adapt to changes in the environment (Perry et al. 1987; Simard et al. 1997A). In contrast, advanced regeneration Douglas-fir seedlings sampled from the openings were associated with a significantly less diverse assemblage of ectomycorrhizal fungi than were the Douglas-fir seedlings sampled from the forest (Figure 1). Advanced regeneration Douglas-fir seedlings growing in openings may be unable to support some species of ectomycorrhizal fungi in the absence of fungal connections with mature trees (Simard et al. 1997B).

MANAGEMENT IMPLICATIONS

Clearcut logging can reduce the quantity and diversity of ectomycorrhizal fungal inoculum. For this reason, refuge species (e.g., *Arctostaphylos uva-ursi, Betula* spp., and *Populus* spp.) on clearcut sites are considered important for the maintenance of ectomycorrhizal inoculum and for successful stand regeneration in these Interior Dry Douglas-fir forests.

REFERENCES

Bealle-Statland, C. 1998. Stand structure and growth estimates for the Opax Mountain silvicultural systems trial. *In* Workshop Proceedings. A. Vyse, C. Hollstedt, and D. Huggard (editors). Research Branch, B.C. Ministry of Forests, Victoria, B.C. Working Paper 34/1998. pp. 136–48.

Christy, E., P. Sollins, and J.M. Trappe. 1982. First year survival of *Tsuga heterophylla* without mycorrhizae and subsequent ectomycorrhizal development on decaying logs and mineral soil. Canadian Journal of Botany 60:1601–6.

Hagerman, S.M., M.D. Jones, G.E. Bradfield, M. Gillespie, and D.M. Durall. 1999. Effects of clear-cut logging on the diversity and persistence of ectomycorrhizae at a subalpine forest. Canadian Journal of Forestry Research 29:124–34.

Harley, J.L. and Smith S.E. 1983. Mycorrhizal symbiosis. Academic Press, London, UK.

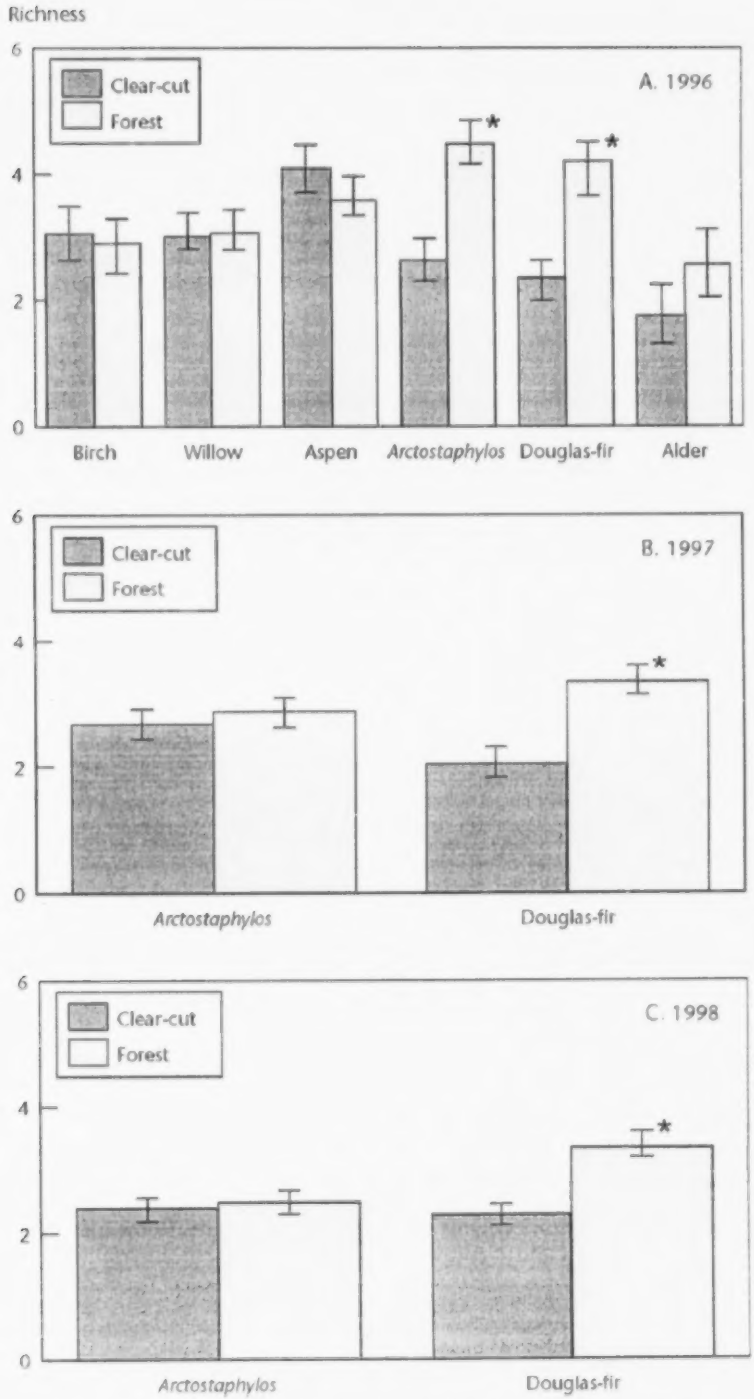

FIGURE 1 *Richness of mycorrhizae (per plant) associated with selected refuge species in clearcut and forest locations in 1996, 1997, and 1999. Bars marked with an asterisk differ significantly ($p < 0.05$).*

Harvey, A.E., M.F. Jurgensen, and M.J. Larsen. 1980. Clearcut harvesting and ectomycorrhizae: survival of activity on residual roots and influence of bordering forest stand in western Montana. Canadian Journal of Forestry Research 10:300–3.

Horton, T.R., T.D. Bruns, and V.T. Parker. 1999. Ectomycorrhizal fungi associated with *Arctostaphylos* contribute *Pseudotsuga menziesii* establishment. Canadian Journal of Botany 77:93–102.

Parke, J.L., R.G. Linderman, and J.M. Trappe. 1984. Inoculum potential of ectomycorrhizal fungi in forest soils of southwest Oregon and northern California. Forest Science 30:300–4.

Parsons, W.F.J., S.L. Miller, and D.H. Knight. 1994. Root-gap dynamics in a lodgepole pine forest: ectomycorrhizal and nonmycorrhizal fine root activity after experimental gap formation. Canadian Journal of Forestry Research 24:1531–8.

Perry, D.A., M.M. Meyer, D. Egeland, S.L. Rose, and D. Pilz. 1982. Seedling growth and mycorrhizal formation in clearcut and adjacent, undisturbed soil in Montana: a greenhouse bioassay. Forest Ecology Management 4:261–73.

Perry, D.A., R. Molina, and M.P. Amaranthus. 1987. Mycorrhizae, mycorrhizospheres and reforestation: current knowledge and research needs. Canadian Journal of Botany 17:929–40.

Simard, S.W., R. Molina, J.E. Smith, D.A. Perry, and M.D. Jones. 1997A. Shared compatibility of ectomycorrhizae on *Pseudotsuga menziesii* and *Betula papyrifera* seedlings grown in mixture in soils from southern British Columbia. Canadian Journal of Forestry Research 27:331–42.

Simard, S.W., D.A. Perry, J.E. Smith, and R. Molina. 1997B. Effects of soil trenching on occurrence of ectomycorrhizas on *Pseudotsuga menziesii* seedlings grown in mature forests of *Betula papyrifera* and *Pseudotsuga menziesii*. New Phytology 136:327–40.

AUTHORS

* ***Correspondence to:*** **Shannon M. Hagerman**, Department of Biology, Okanagan University College, Kelowna, BC V1V 1V7.

E-mail: smhagerm@okcins.okanagan.bc.ca

† Department of Biology, Okanagan University College

Effects of riparian buffer width on high-elevation songbird communities

DEVON HAAG* AND THOMAS DICKINSON†

INTRODUCTION

In temperate areas, riparian zones occupy a minor proportion of the overall land base, yet receive disproportionately high use by wildlife (Bunnell and Dupuis 1993). The presence of water contributes to greater levels of plant productivity and diversity, creating a structurally complex vegetation community that is attractive to many terrestrial species. In many areas of British Columbia, riparian zones support a greater avian diversity and richness than occurs in all other habitats (Bunnell et al. 1995).

Timber extraction on Crown lands in British Columbia is regulated by the Forest Practices Code. When harvesting occurs adjacent to riparian habitats, legislation requires the retention of forested buffers, or the creation of riparian management areas. Initially developed for the protection of aquatic habitat and water quality, the objectives of riparian management areas also include the protection of terrestrial wildlife values (British Columbia Ministry of Forests and B.C. Ministry of Environment, Lands and Parks 1995). Currently, minimum buffer widths are based on stream size, the presence of fish, and use as a community watershed. It is not yet known if these criteria are sufficient to meet the habitat needs of riparian- and forest-associated terrestrial wildlife species.

Headwater streams, often small and rarely containing fish, receive little or no protection and may be at particular risk of riparian habitat degradation. In high-elevation forests, these riparian areas are used not only by riparian-associated bird species, but also by those species requiring interior and mature forest habitats. As such, it is important to determine both the effects of this habitat loss on subalpine songbird communities and the ability of riparian buffers to afford alternative songbird habitat.

Our project examines the influence of riparian management strategies on songbird conservation. The primary goal of the research was to assess the effectiveness of different buffer widths in providing suitable breeding habitat for songbirds along small, high-elevation streams. The project objectives were twofold:

1. to determine the effects of riparian buffer width on the structure and composition of breeding songbird communities; and
2. to describe the habitat use and associations of particular songbird species.

Citation —

Haag D.A. and T.E. Dickinson. 2000. Effects of riparian buffer width on high-elevation songbird communities. *In* Proceedings. From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 137–40.

METHODS AND MATERIALS

Study Area

The research was conducted within Tree Farm License (TFL) 35, a 30 000 ha area located in the Kamloops Forest Region and operated by Weyerhaeuser Canada. Study sites were located in both the mid-elevation Montane Spruce (MS) and the high-elevation Engelmann Spruce–Subalpine Fir (ESSF) biogeoclimatic zones. In 1998, 10 study sites were located throughout the TFL and included two replicates each of four treatments and two replicate controls. The four treatment widths were defined as "very narrow" (~ 2 m), "narrow" (~ 12 m), "medium" (~ 30 m), and "wide" (~ 60 m). Controls were located along streams with approximately 250 m of undisturbed forest extending into the upland. Site selection was limited to those small streams (~ 5 m wide) with recent harvesting (< 4 years) on one side and forested habitat on the other side.

Sampling Methods

Spot-mapping was used to census songbirds breeding in the study area (Bibby et al. 1992). This method involves repeated visits to a well-marked grid, within which all songbird locations are recorded. One 300 × 150-m grid, constructed at each study site, was oriented lengthwise along one side of the stream. Songbird locations were recorded onto 1:1500 maps of each grid. In 1998, a single survey was performed at each site. As spot-mapping requires a minimum of six visits to a site, the 1998 data was sufficient to assess species presence or absence only. In 1999, seven surveys were conducted at each site.

In 1999, behaviour sampling examined the selection and utilization of habitat attributes by songbird species. Focal sampling with continuous recording (Martin and Bateson 1993) tracked individuals and noted movements and locations. From these data, the vegetation species and vegetation layers preferred by a species can be determined and movement patterns quantified. Sampling concentrated on the foraging and territorial display behaviour of the winter wren (*Troglodytes troglodytes*) and the yellow-rumped warbler (*Dendroica coronata*). Behaviour observations were carried out within, and immediately outside, each study grid. Individual birds were followed for as long as possible and all activities were described into a small tape recorder. For each movement or location, data was recorded under six categories: activity, substrate, relative position on the substrate, height above ground, movement direction, and distance moved.

In 1998, vegetation sampling quantified habitat structure and vegetation composition. Twelve vegetation plots, systematically placed in each grid, were used to describe the vegetation community at successive distances from the stream. Circular plots of 10-m radius (0.03 ha) were employed to estimate tree density by species and diameter class, average canopy height, and canopy cover. Shrub and ground cover was estimated along two 20-m line transects placed in each plot, oriented at right angles to each other, and intersecting at the plot centre. The line-intercept method (Cook and Stubbendieck 1986) was used to measure shrub cover by species, height class, and vigour. Ground cover was measured by cover type and height class with the point-intercept method (Bonham 1989).

Analysis

All bird observations from the 1999 field season were digitized into a GIS (ARCVIEW 3.1) to delineate songbird territories. The process of determining territory size, shape, and location is currently under way. Community parameters, such as richness, diversity, and similarity, will be estimated from these data, and species-specific territory density and distribution calculated and compared across treatments. Concurrent analysis of breeding bird behaviour and vegetation data will indicate vegetation features that influence the presence of particular species. To date, only preliminary descriptive analyses have been performed on the data; statistical analyses will be conducted in the winter and spring of 1999/2000.

RESULTS AND DISCUSSION

We recorded 22 songbird species within the study grids during the single survey in 1998. By comparison, multiple surveys in 1999 recorded 46 songbird species within the study grids. In the forested buffers and control sites, the most frequently encountered species included the golden-crowned kinglet (*Regulus satrapa*), winter wren, Townsend's warbler (*Dendroica townsendi*), and yellow-rumped warbler. Two species, the brown creeper (*Certhia americana*) and the boreal chickadee (*Parus hudsonicus*), were recorded exclusively in the control sites. Conversely, species that commonly occurred in the harvested areas included the dark-eyed junco (*Junco hyemalis*), chipping sparrow (*Spizella passerina*), and American robin (*Turdus migratorius*).

In our behaviour sampling, we recorded 18 511 seconds of bird activity in total. This consisted of 9862 seconds of foraging activity, 10 616 seconds of display and territorial behaviour, and 523 seconds of other activity types, which included calling, perching, and preening. We observed winter wrens on eight sites for a total of 8720 seconds and yellow-rumped warblers on seven sites for 5492 seconds. Additional data were also collected on golden-crowned kinglets and Townsend's warblers whenever possible.

Preliminary vegetation analysis has concentrated on riparian habitat characteristics across treatments. Small diameter trees dominated the very narrow and medium treatments, while the highest mean number of large trees was recorded in the wide treatment and the controls. The lowest mean shrub cover and number of vertical shrub layers occurred in the very narrow treatment. By contrast, the greatest mean shrub cover and number of shrub layers were present in the wide and control sites.

Our preliminary results support the existing literature; particular species are forest specialists, while other species are either disturbance-tolerant forest birds or habitat generalists. Brown creepers and boreal chickadees appear the most sensitive to harvesting effects. Other species, such as winter wrens and Townsend's warblers, are strongly associated with forest habitats, but seem tolerant of edges and adjacent clearcuts. Generalist species, including dark-eyed juncos and chipping sparrows, use both clearcuts and forest edges and are likely to dominate songbird communities in heavily harvested forests. A combination of forested and harvested habitats can actually increase species richness across a landscape by attracting both forest- and open-habitat species. However, decreasing forest area results in a reduced number of forest species; a landscape that is moderately or heavily disturbed may contain few of the forest species that commonly occur in unharvested habitats. Thus, it is important for forest managers to know the potential effects of different harvest strategies so that they may decide what species to manage for and how best to achieve their management objectives.

REFERENCES

Bibby, C.J., N.D. Burgess, and D.A. Hill. 1992. Bird census techniques. Academic Press: Harcourt Brace and Company Publishers, London, UK.

Bonham, C.D. 1989. Measurements for terrestrial vegetation. John Wiley and Sons, New York, N.Y.

British Columbia Ministry of Forests and B.C. Ministry of Environment, Lands and Parks. 1995. Riparian management area guidebook. B.C. Forest Practices Code, Victoria, B.C.

Bunnell, F. and L. Dupuis. 1993. Riparian habitats in British Columbia: their nature and role. *In* Riparian habitat management and research. K.H. Morgan and M.A. Lashmar (editors). Fraser River Action Plan: Workshop Proceedings.

Bunnell, P., S. Rautio, C. Fletcher, and A. VanWoudenberg. 1995. Problem analysis of integrated resource management of riparian areas in British Columbia. B.C. Ministry of Forests and B.C. Ministry of Environment, Lands and Parks, Victoria, B.C. Working Paper No. 11.

Cook, W.C. and J. Stubbendieck. 1986. Range research: basic problems and techniques. Society for Range Management, Denver, Colo.

Martin, P. and P. Bateson. 1993. Measuring behaviour: an introductory guide. Cambridge University Press, Cambridge, UK.

AUTHORS

* ***Correspondence to:*** **Devon A. Haag,** Centre for Applied Conservation Biology (Faculty of Forestry), University of British Columbia, 3004-2424 Main Mall, Vancouver, BC V6T 1Z4.

E-mail: devon@direct.ca

† Department of Biological Sciences, University College of the Cariboo, Kamloops, B.C.

A systematic method for identifying priority conservation areas using wildlife habitat relationships and observed locations of rare species

LEANNA WARMAN* AND ANTHONY SINCLAIR†

INTRODUCTION

In an attempt to minimize the loss of biological diversity, large amounts of time, money, and effort have been focused on preserving natural habitats (Sinclair et al. 1995). Management and conservation planning decisions are required immediately to protect the greatest amount of biological diversity possible. Many different approaches have been developed to determine the best areas for conserving a desired species or subset of species (Margules and Redhead 1995; Faith and Walker 1996; Williams et al. 1996; Csutsi et al. 1997; Pressey et al. 1997). Some of these conservation-planning approaches are more efficient than others in their ability to identify a greater diversity of natural areas or species for conservation (Pressey and Nicholls 1989). The efficiency of identifying reserve systems is critical if the goal is to conserve the biological diversity of a region before the opportunities for reserve selection are limited by development. Because funds for conservation are insufficient to save everything, planning approaches must identify the optimum allocation of resources to save the maximum amount of habitat and species.

The habitat found in the south Okanagan and lower Similkameen valleys is considered one of Canada's three most endangered ecosystems (Bryan et al. 1994). Most ecological reserves, provincial parks, and wildlife management areas in these valleys were selected using an *ad hoc* approach. This approach has led to an uneven representation of natural features within the protected areas, thereby decreasing the potential for conservation of the biological diversity within the region (Pressey 1994). If the rate of habitat loss continues without protecting the essential habitats required to maintain populations, many species will be extirpated from the region (Noss 1994).

Our project applies a systematic conservation planning approach to the south Okanagan and lower Similkameen valleys to identify multiple-species conservation areas. The overall goal of this study is to identify priority areas for the conservation of the region's endangered and vulnerable biodiversity when different constraints are included in the selection process. These constraints include the economic, social, and biological factors that influence the selection of the priority sets of areas for conservation. The objective is to compare the priority sets of conservation areas with different constraints to identify the consequences of political, economic, or biological decisions on achieving explicit regional conservation goals.

Citation —

Warman, L.D. and A.R.E. Sinclair. 2000. A systematic method for identifying priority conservation areas using wildlife habitat relationships and observed locations of rare species. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 141–4.

MATERIALS AND METHODS

The Ministry of Environment, Lands and Parks has developed extensive data sets for endangered and vulnerable species and habitats in the study area. The data consist of geo-referenced digital data sets that are compatible with Environmental Systems Research Institute Geographic Information Systems (GIS). The polygons identified in the 1:20 000 scale terrestrial ecosystem mapping of the study area are used as the site data for the selection of conservation areas. Biological data sets used to identify conservation criteria include:

- species occurrence data maintained by the Conservation Data Centre and by the local BC Environment office;
- 29 species habitat suitability models (Warman et al. 1998);
- rare plant community distributions (Warman 1997); and
- rare invertebrate inventory data provided by Dr. Scudder at the University of British Columbia.

The data sets that identify the constraints used in the analyses include:

- 1:20 000 scale TRIM data for roads and rights of way;
- land tenure information provided by BC Environment, LandData BC, and the Regional District of the Okanagan Similkameen; and
- resource uses identified by the ministries of Forests and Energy and Mines, and by the Agricultural Land Reserve.

The National Parks and Wildlife Service (NPWS) in New South Wales, Australia, has recently produced conservation planning software, called C-PLAN, to identify conservation areas in landscapes, which are subject to the effects of human development. C-PLAN is designed as a decision-support system which, together with ARCVIEW (a GIS), maps the options for achieving explicit regional conservation goals. The C-PLAN algorithm selects areas of land or water in an iterative manner based on the extent or number of features that are located within a site. Features are defined as any attributes considered important for conservation, and can be physical, biological, or cultural. These attributes are used to calculate the irreplaceability values of a site, identify conservation targets, and select priority sites for conservation. Irreplaceability provides an objective measure used to identify sites that are essential for achieving explicit regional conservation goals. The selection method used in C-PLAN applies a complementarity approach. This approach builds on existing conservation networks, such as parks and protected areas, by selecting new areas with species or habitats not already adequately conserved in existing conservation networks. This procedure maximizes the conservation of biodiversity, at the least cost, for the area required or the location of the parcels of land relative to other land uses (Pressey et al. 1997).

RESULTS AND DISCUSSION

We determined the reliability of the wildlife habitat models using species occurrence databases maintained by the Conservation Data Centre and the Ministry of Environment in Penticton, B.C. Data sets consisted of presence data collected by both researchers and the public. Model reliability was measured by identifying the proportion of polygons in each habitat-rating category for every species habitat model that contained one or more occurrence records. The results indicate that the wildlife habitat-use predictions are reasonable since a greater proportion of the polygons rated as "high quality" in each of the species habitat models have species occurrence records (Figure 1). These are preliminary results, and therefore we have not determined the statistical significance of these data.

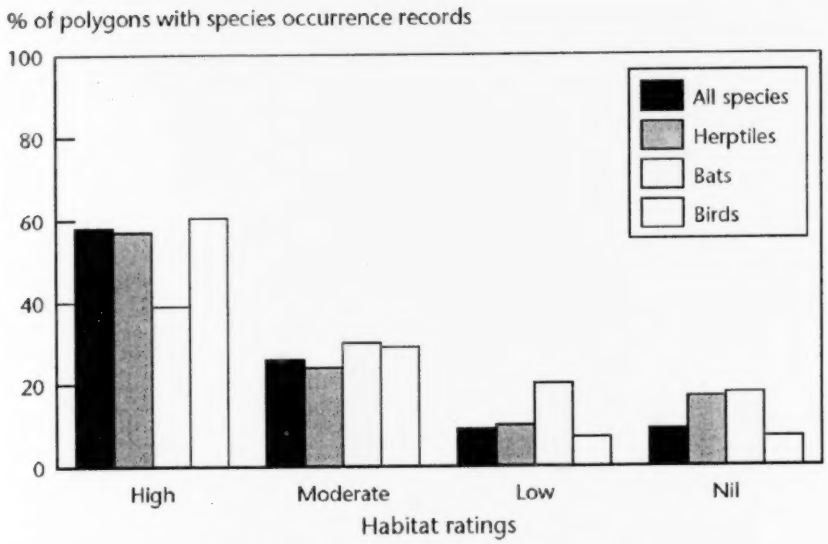

FIGURE 1 *Reliability assessment of the wildlife habitat models.*

The preliminary results from the analyses of priority conservation areas identified, as "highly irreplaceable," riparian, shrub-steppe, and grassland areas occurring in the valley bottom . These areas are in the greatest conflict with agriculture and urban development. In the next phase of the project, we will determine how the land tenure and agricultural zoning plans affect the conservation plans for the region.

The great advantage of this conservation planning approach is its ability to identify representative networks of reserves, which maximize the proportion of biodiversity conserved within a region. The systematic, defensible, and flexible plans that result are pro-active rather than reactive. Therefore, priority conservation areas can be identified before harmful effects occur. This will enhance our ability to lobby and negotiate with government agencies and industry. Efficient and defensible conservation plans are essential for the successful conservation of biota within this region. These plans must be considered for the conservation of the biota within the province, nation, and continent.

REFERENCES

Bryan, A.D., M.J. Sarell, and J.A. Luoma. 1994. A national treasure: natural areas of the south Okanagan and lower Similkameen valleys. Wildlife Branch, B.C. Environment, Penticton, B.C.

Csutsi, B., S. Polasky, P.H. Williams, R.L. Pressey, J.D. Camm, M. Kershaw, A.R. Kiester, B. Downs, R. Hamilton, M. Huso, and K. Sahr. 1997. A comparison of reserve selection algorithms using data on terrestrial vertebrates in Oregon. Biological Conservation 80:83–97.

Faith, D.P. and P.A. Walker. 1996. Integrating conservation and development: incorporating vulnerability into biodiversity-assessment of areas. Biodiversity Conservation 5:417–29.

Margules, C.R. and T.D. Redhead. 1995. Guidelines for using the BioRap methodology and tools. *In* Series: BioRap, rapid assessment of biodiversity priority areas. CSIRO, Australia.

Noss, R.F. 1994. The Wildlands Project: land conservation strategy. *In* Futures by design. New Society Publishers, Gabriola Island, B.C. pp. 127–65.

Pressey, R.L. 1994. *Ad hoc* reservations: forward or backward steps in developing representative reserve systems? Conservation Biology 8(3):662–8.

Pressey, R.L. and A.O. Nicholls. 1989. Efficiency in conservation evaluation: scoring versus iterative approaches. Biological Conservation 50:199–218.

Pressey, R.L., H.P. Possingham, and J.R. Day. 1997. Effectiveness of alternative heuristic algorithms for identifying indicative minimum requirements for conservation reserves. Biological Conservation 80:207–19.

Sinclair, A.R.E., D.S. Hik, O.J. Schmitz, G.G.E. Scudder, D.H. Turpin, and N.C. Larter. 1995. Biodiversity and the need for habitat renewal. Ecological Applications 5(3):579–87.

Warman, L. 1997. Rare plant communities of the South Okanagan Conservation Strategy Study Area. Wildlife Branch, B.C. Environment, Penticton, B.C.

Warman, L., S. Robertson, A. Haney, and M. Sarell. 1998. Habitat capability and suitability models for 34 wildlife species: using Terrestrial Ecosystem Mapping in the South Okanagan and Lower Similkameen Study Area and Forest Cover Mapping in the Penticton Forest District. Wildlife Branch, B.C. Environment, Penticton, B.C.

Williams, P., D. Gibbons, C. Margules, A. Rebelo, C. Humphries, and R. Pressey. 1996. A comparison of richness hotspots, rarity hotspots, and complementary areas for conserving diversity of British birds. Biological Conservation 10(1):155–74.

AUTHORS

* ***Correspondence to:*** Leanna D. Warman, Centre for Biodiversity Research, University of British Columbia, 6270 University Boulevard, Vancouver, BC V6T 1Z4.

E-mail: warman@zoology.ubc.ca

† Centre for Biodiversity Research, University of British Columbia

Small mammals and stand structure in young pine, seed tree, and old-growth forests in southern British Columbia

THOMAS SULLIVAN*, DRUSCILLA SULLIVAN†, AND PONTUS LINDGREN†

INTRODUCTION

Alternative silvicultural systems to clearcutting are receiving considerable attention in the Pacific Northwest forests of North America. Understanding the implications of these harvesting systems on stand structure and biodiversity through time is a fundamental aspect of forest ecosystem management. This study was designed to test the hypotheses that:

1. stand structure attributes (species diversity and structural diversity of herb, shrub, and tree layers) will increase from young pine to seed-tree to old-growth forest; and
2 as a measure of wildlife habitat diversity, species richness and diversity of small mammal communities on the forest floor will increase in a similar manner.

MATERIALS AND METHODS

The study area was within mixed Douglas-fir (*Pseudotsuga menziesii* var. *glauca*)–lodgepole pine (*Pinus contorta* var. *latifolia*) forests within the Montane Spruce biogeoclimatic zone near Summerland in south-central British Columbia. This retrospective study had three replicate stands each of 17-year-old "young pine" (clearcut harvested), "seed-tree" composed of young pine with Douglas-fir seed-trees, and uncut "old-growth" composed primarily of Douglas-fir and lodgepole pine. Stand structure (coniferous tree layers) and understorey vegetation (moss, herb, and shrub-deciduous tree layers) were measured in each stand. Habitat diversity was measured by the species richness, species diversity, and structural diversity of these vegetative layers. Small mammal communities on the forest floor were sampled intensively from 1995 to 1997 in all stands.

RESULTS AND DISCUSSION

Mean total percent cover and crown volume index of herbs and mosses were similar among treatment stands. These measurements for shrub and deciduous tree layers were highest in young pine stands and lowest in old-growth stands. Mean species richness of herbs and coniferous trees was similar among treatment stands, but for shrubs and deciduous trees it was highest in the young pine stands. Mean

CITATION —

Sullivan, T.P., D.S. Sullivan, and P.M.F. Lindgren. 2000. Small mammals and stand structure in young pine, seed-tree, and old-growth forests in British Columbia. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 145–6.

species diversity in the herb and shrub-deciduous tree layers was similar among treatment stands, but for coniferous trees was higher in the seed-tree and old-growth stands than in the young pine stands. Mean species richness of height classes in herb and shrub-deciduous tree layers appeared consistently highest in the young pine, but for coniferous trees was highest in the seed-tree stands. Mean structural diversity of the shrub-deciduous tree layer was highest in the young pine and lowest in the old-growth stands.

Mean abundance of red-backed voles (*Clethrionomys gapperi*) was consistently higher in the old-growth stands than in young pine or seed-tree stands. Mean numbers of Northwestern chipmunks (*Tamias amoenus*), heather voles (*Phenacomys intermedius*), western jumping mice (*Zapus princeps*), montane shrews (*Sorex monticolus*), and common shrews (*S. cinereus*) were higher in the seed-tree or young pine stands than in the old-growth stands. Mean abundance of meadow voles (*Microtus pennsylvanicus*) was highest in seed-tree stands. Deer mice (*Peromyscus maniculatus*), long-tailed voles (*Microtus longicaudus*), and short-tailed weasels (*Mustela erminea*) had similar mean numbers among treatment stands.

Demographic parameters of survival and body mass of the major species were similar among treatment stands. Mean number of successful pregnancies was highest for red-backed voles in old-growth forest and for Northwestern chipmunks in seed-tree stands. Mean species richness and diversity of small mammals was higher in the seed-tree and young pine stands than in the old-growth stands.

Timber harvesting in mixed Douglas-fir–lodgepole pine forests should use the seed-tree system, which provides natural stand structure attributes to help manage the forest landscape for biodiversity objectives.

AUTHORS

* ***Correspondence to:*** **Thomas P. Sullivan**, Applied Mammal Research Institute, 11010 Mitchell Avenue, R.R. #3, Summerland, BC V0H 1Z0.

E-mail: sullivan@bc.sympatico.ca

† Applied Mammal Research Institute

Indigenous knowledge and occidental science: How both forms of knowledge can contribute to an understanding of sustainability

CHARLENE HIGGINS*

INTRODUCTION

The concepts of sustainability and sustainable development have become powerful and controversial themes that continue to provide the foundation for a number of local, national, and international initiatives. Proposals for change are often revealed in terms of their contributions to sustainability (Barkin 1998). However, one of the problems in trying to achieve sustainability is knowing what it means. The Brundtland Report (World Commission on Environment and Development 1987) stated that sustainable development required the conservation of plant and animal species, and defined sustainable development as "a process of change in which the exploitation of resources and technological development were in harmony with current, and future, human needs and aspirations." This report recognized the role Indigenous Peoples must play in sustainable development, and recommended that Indigenous Peoples be given a "decisive voice" in resource management decisions that may affect them.

The Rio Declaration was drafted five years later, in 1992, at the Earth Summit in Rio de Janeiro. This declaration stated that Indigenous Peoples have a vital role in environmental management and development, and clearly established the relevance of their knowledge and traditional practices in sustainable development, and the need to protect their rights. The Earth Summit recognized that the use of traditional knowledge could contribute to the conservation of biodiversity and sustainable ecosystem management. The Convention on Biological Diversity was opened for signature at the Earth Summit. This Convention was an attempt by the global community to commit to sustainable development. Article 8(j) of the Convention specifically refers to the importance of Indigenous knowledge (IK) in the conservation and sustainable use of biodiversity, by stating the need to:

> *respect, preserve and maintain the knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biodiversity, the need to promote the wider application with the approval and involvement of the holders of such knowledge, and to encourage the equitable sharing of benefits arising from the utilization of such knowledge, innovations and practices.*

In an effort to understand sustainability, I discuss this concept from both scientific and Indigenous perspectives. The objectives of this paper are to identify Indigenous knowledge (IK) as a critical information gap, and highlight how the combined use of Indigenous knowledge and Western scientific knowledge could facilitate a greater understanding of sustainability. Research and support for both forms of knowledge is needed to better address the full range of issues related to the sustainable

CITATION —

Higgins, C. 2000. Indigenous knowledge and occidental science: How both forms of knowledge can contribute to an understanding sustainability. *In* Proceedings, From science to management and back: a science forum for southern interior ecosystems of British Columbia. C. Hollstedt, K. Sutherland, and T. Innes (editors). Southern Interior Forest Extension and Research Partnership, Kamloops, B.C., pp. 147–151.

management of ecosystems for all resources and values. The co-existence and use of both forms of knowledge will help to develop holistic sustainable management models.

SUSTAINABILITY: DEFINITIONS AND PERSPECTIVES

An Indigenous Perspective

Sustainability has been defined as: "the ability of an ecosystem to maintain ecological processes and functions, biological diversity, and productivity over time" (Dunster and Dunster 1996).

Sustainability from one Indigenous perspective is synonymous with survival. Sustainability is inextricably linked to a dependence on the land and resources, and use is based on a holistic spiritual and respectful approach. There is a spiritual, ecological, economic, and social bond between the land and the people. Aldo Leopold, a leading ecologist in the early 1950s and a founder of the conservation movement, termed this connectivity—one in which there is no separation between the soils, water, plants, animals, and people—the *land ethic* (Leopold 1949). He stated that: "a land ethic could not prevent the alteration, management and use of these resources, but that it did affirm their right to continued existence, and at least in spots, their continued existence in a natural state."

Sustainability in this context is not just about the environment and development, it is about the survival of people who depend on the land. Thus, strategies developed to promote sustainability should focus on the importance of meaningful, local participation (Barkin 1998). Because of the close link between the social and economic elements of sustainable management, policies for strengthening the economic development of the various resource sectors are unlikely to be successful in the long run if they do not integrate environmental, social, and cultural concerns. Another way of looking at this is to view sustainability as composed of three overlapping components: economic, environmental, and social; the area of overlap represents a balance or achievement of sustainability (Figure 1). Environmental policies and cultural values need to be integrated with both economic and social elements. The achievement of balance and the integration of the social, cultural, economic, and environmental values into practices at the management level will, of course, involve trade-offs—choices will have to be made.

There is increasing recognition that the use of Indigenous knowledge and the application of Indigenous natural resource management systems provide effective strategies for the sustainable use of natural resources (Posey 1996). Several reasons exist to incorporate IK into the planning and management of ecosystems: IK is holistic; Indigenous Peoples' systems of traditional use tend to have a low impact on biological diversity; management approaches are based on self-regulation and are

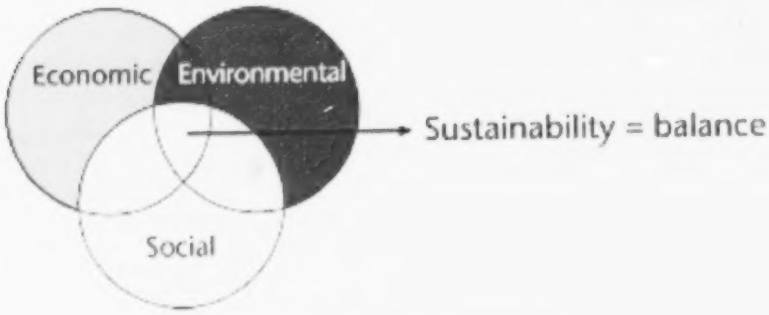

FIGURE 1 *Sustainability is composed of three overlapping components.*

decentralized, built on consensus, and enforced through social sanctions according to customary law, cultural tradition, and local knowledge (IUCN 1997).

Comparison of Indigenous Knowledge and Occidental Science

Science is defined as: (1) knowledge acquired by study, mastery, trained skill; (2) a body of knowledge, laws or principles; and (3) the state of fact of knowing; knowledge in the sense as opposed to belief or opinion.

All of these definitions are applicable to Indigenous knowledge (Augustine 1997). Indigenous knowledge is a disciplined approach to knowing and understanding the nature of reality, systems of relationships, and the processes of the universe. However, it cannot be separated from other aspects of daily existence, such as ethics and spirituality (Peat 1994). Seeking truth and coming to understanding require the study of cycles, relationships, and connections between things (Augustine 1997). Knowledge of medicines provides an example of how Indigenous wisdom can be applied in a Western scientific context. For instance, more than 100 Native medicines exist, aspirin being one of them (Augustine 1997). Knowledge of medicines requires precise information about the environment, the seasonal patterns of the plants, and their ecological requirements. Thus, the acquisition of this knowledge and the use of these medicines by Indigenous Peoples demonstrates the use of their knowledge in a scientific context. This example highlights the non-random and precise nature of Indigenous knowledge. Use of fire, farming methods, hunting methodologies, and knowledge of the natural ecology and biology of wildlife are other examples of Indigenous knowledge as a base of expertise associated with observation, classification, and comparison (Augustine 1997). For these reasons, Indigenous knowledge must be classified as a science.

Use of Indigenous Knowledge in Resource Management

The environmental field became interested in Indigenous knowledge when researchers began to look for alternative approaches to Western science and technology, and studies shifted from theoretical to applied approaches (Simpson 1999). As both the global and local communities search for new ways to manage natural resources and solve environmental crises, Indigenous knowledge is increasingly sought after. However, despite this recognition by some members of society and academia, it is still rare that IK is accepted on *par* with occidental science. Unlike classic Euro-centric science, it is seldom perceived as objective quantifiable knowledge. Much of mainstream society still believes that Western scientific knowledge is "better" or more "reliable" than knowledge generated by Indigenous systems (Simpson 1999). In most cases, non-Western knowledge and traditions are only accepted when they support approved orthodox doctrines (Deloria 1997).

Indigenous knowledge must be used as it is, for what it is, and not changed to fit Western scientific paradigms. A fundamental component of the use and incorporation of Indigenous knowledge is that the knowledge holders control how it is used. This will minimize the chance of assimilation, misappropriation, and exploitation, and bring forth a greater desire by Indigenous communities to share this knowledge and participate in co-management of the land and resources. Indigenous knowledge holders must be respected as experts; this knowledge must be respected for what it is on Indigenous terms, including its spiritual basis, ethics, and its dynamic and creative nature (Simpson 1999). Most importantly, Indigenous communities must have complete control over the documentation and use of their knowledge.

Future Steps and Challenges

A greater move toward the co-management of natural resources that fully involves Indigenous Peoples would permit the co-existence of knowledge and practices which would enhance sustainability and

include ethical concerns. Developing policies and practices to use Indigenous knowledge will contribute to sustainable resource management and the conservation of biological diversity. To guarantee the successful incorporation of Indigenous knowledge, as well as the protection of this information, Indigenous Peoples must control the collection and use of this information for resource management. Article 8(j) of the Convention on Biological Diversity states that arising from the utilization of such knowledge, innovations, and practices, provisions shall be made for the equitable sharing of benefits with the holders of this knowledge. Through the use and incorporation of IK, Indigenous Peoples can make unique contributions to stabilizing and sustaining the use of the world's ecosystems.

The following recommendations promote the co-existence of Indigenous knowledge with Western science.

- Research should be requested by the Indigenous community to ensure it meets their needs. Research and documentation are needed to conserve and protect IK.
- Community ownership and prior informed consent over the use of the information (Article 8(j) and Article 15 of the Convention on Biological Diversity [CBD]). The survival of IK will be best achieved through its use.
- Identification of regimes to protect Indigenous knowledge, innovations, and practices from misappropriation and exploitation. Research and documentation by the knowledge holders will help to conserve and protect Indigenous knowledge, innovations, and practices. There is an urgency to do this while the Elders are still alive.
- Support for the involvement of all members of the community including Elders, women, and youth. This will strengthen the Indigenous language and community identity.
- Training for Elders, women, and youth to ensure that the expertise remains in the community, and that data collection and analytical skills are taught to Indigenous researchers.
- Access to the equitable sharing of benefits derived from the use of Indigenous knowledge, innovations, and practices (Article 8(j) CBD). This would provide Indigenous communities with the means to develop capacity and pursue their own development.
- Case studies on co-management systems that would examine the ways and means of managing natural resources, while supporting the co-existence of knowledge regimes.

CONCLUSION

Indigenous knowledge is often neglected, but can be vital in the holistic management of biodiversity. To protect biodiversity, Indigenous knowledge also needs protection. Research and documentation are necessary before Indigenous knowledge can be incorporated into resource management. Documentation is also an important element in conserving and protecting this knowledge. Experts and Elders, from both Aboriginal and scientific backgrounds, must be involved in the use of Indigenous knowledge in the sustainable management of forests, and the long-term conservation of the biological diversity of ecosystems. Sustainability can only really be achieved when both the environmental, traditional, and cultural diversity of particular communities and their regions are protected and understood in unique specificity.

There is a general agreement among practitioners that sustainable development policies cannot be designated or implemented from above. Some scientists recognize that partnerships and collaborative management are essential for understanding and striking a balance of risks and successes in sustaining ecosystems as a whole (Holder and Andersen 1994). To be successful, they require the direct participation of the intended beneficiaries and others who might be affected (Barkin 1998). In this formulation, sustainability is not just about economics or the environment—it is about the active participation of people.

REFERENCES

Augustine, S.J. 1997. Traditional Aboriginal knowledge and science versus occidental science. Prepared for the Biodiversity Convention Office of Environment Canada. Unpublished report.

Barkin, D. 1998. Wealth, poverty and sustainable development. Centro de Ecologia y Desarrollo, A.C.

Deloria, V. 1997. Red earth, white lies: Native Americans and the myth of scientific fact. Fulcrum Publishing, Golden, Colo.

Dunster, J and K. Dunster. 1996. Dictionary of natural resource management. UBC Press, Vancouver, B.C.

IUCN. 1997. Inter-commission on Indigenous Peoples. Indigenous Peoples and sustainability: Cases and actions. International Books, Utrecht.

Leopold, A. 1949. A Sand County almanac: With essays on conservation from Round River. Oxford University Press, Oxford, UK.

Peat, F.D. 1994. Lighting the seventh fire: The spiritual ways, healing and science of the Native American. Carol Publishing, New York, N.Y.

Posey, D.A. 1996. Traditional resource rights: International instruments for protection and compensation for Indigenous Peoples and local communities. IUCN, Gland, Switzerland and Cambridge, UK.

Simpson, L. 1999. The construction of traditional ecological knowledge: Issues, implications and insights. PhD thesis. University of Manitoba, Winnipeg, Manitoba.

World Commission on Environment and Development. 1987. Our common future. Oxford University Press, Oxford, UK.

AUTHOR

* ***Correspondence to:*** Charlene Higgins, There's More to Forests, Forest Policy Advisory Services, 158 Thor Drive, Kamloops, B.C. V2C 1P4.

E-mail: chiggins@mail.ocis.net